

# THE SIRENIAN METAXYTHERIUM (MAMMALIA: DUGONGIDAE) IN THE BADENIAN (MIDDLE MIOCENE) OF CENTRAL EUROPE

Daryl P. DOMNING<sup>1</sup> & Peter PERVESLER<sup>2\*)</sup>

## KEYWORDS

<sup>1</sup> Laboratory of Evolutionary Biology, Department of Anatomy, Howard University, Washington, D.C. 20059, USA;

<sup>2</sup> University of Vienna, Department of Palaeontology, Althanstrasse 14, A-1090 Wien, Austria;

<sup>\*</sup> Corresponding author, peter.pervesler@univie.ac.at

Metaxytherium  
Dugongidae  
Badenian  
Sirenians  
Miocene

## ABSTRACT

The fossil record of sirenians in the Middle Miocene (Badenian; Langhian-early Serravallian) of the Central Paratethys region (principally eastern Austria) is reviewed, and new specimens are described from the localities of Gainfarn, Baden/Rauchstallbrunngraben, ?St. Margarethen, and Retznei (Austria) and Fazekasboda (Hungary). All these are referred to *Metaxytherium medium* (Desmarest, 1822) Hooijer, 1952, which is the only sirenian here recognized in the Middle Miocene of the Central Paratethys. *Thalattosiren petersi* (Abel, 1904) Sickenberg, 1928 is considered a synonym of *Metaxytherium medium*. This conclusion extends the known geographic range of *M. medium*, and is consistent with the hypothesis that European and North African Miocene and Pliocene *Metaxytherium* formed a single, anagenetically-evolving lineage. Although the area in which "*Thalattosiren petersi*" was thought to occur (mainly the Vienna Basin) was progressively cut off from other marine basins during the course of the Badenian, and could conceivably have supported an endemic sirenian taxon isolated on the northeastern margin of the range of *M. medium*, the few diagnostic specimens available do not appear to support this scenario. *Metaxytherium medium* is considered an ecological generalist among sirenians, inhabiting tropical to warm temperate shallow marine waters and feeding on seagrasses. Its fossil record in the Central Paratethys ends with the Badenian, but its lineage continued in the Mediterranean into the Late Pliocene.

Der Fossilbestand der Sirenen im Mittleren Miozän (Badenium; Langhium-frühes Serravallium) der Zentralen Paratethys (im Prinzip Ostösterreich) wird revidiert und neue Exemplare aus den Lokalitäten Gainfarn, Baden/Rauchstallbrunngraben, ?St. Margarethen, und Retznei (in Österreich) und Fazekasboda (in Ungarn) werden beschrieben. Sie alle sind dem *Metaxytherium medium* (Desmarest, 1822) Hooijer, 1952, der einzigen Seekuh des Mittleren Miozäns in der Zentralen Paratethys, zugeordnet. *Thalattosiren petersi* (Abel, 1904) Sickenberg, 1928 wird als Synonym von *Metaxytherium medium* betrachtet. Diese Schlussfolgerung erweitert die bisher bekannte geographische Verbreitung des *M. medium* und stimmt auch mit der Hypothese überein, dass europäische und nordafrikanische, miozäne und pliozäne Metaxytherien eine einzige, sich anagenetisch entwickelnde Linie repräsentieren. Obwohl das vermutete Verbreitungsgebiet von "*Thalattosiren petersi*" (vor allem das Wiener Becken) im Laufe des Badenium zunehmend von anderen marinen Becken abgeschnitten wurde und so die Bildung eines endemischen Taxons am nordöstlichen Rand des Verbreitungsgebietes von *M. medium* möglich gewesen wäre, geben die wenigen diagnostischen Exemplare keinen Hinweis darauf. *Metaxytherium medium* kann als Generalist unter den Sirenen betrachtet werden, der tropische, warm temperierte, flachmarine Gewässer bewohnt und dort Seegräser beweidet. Der fossile Nachweis in der Zentralen Paratethys endet mit dem Badenium, im Mediterran setzt sich die Linie bis in das Pliozän fort.

## 1. INTRODUCTION

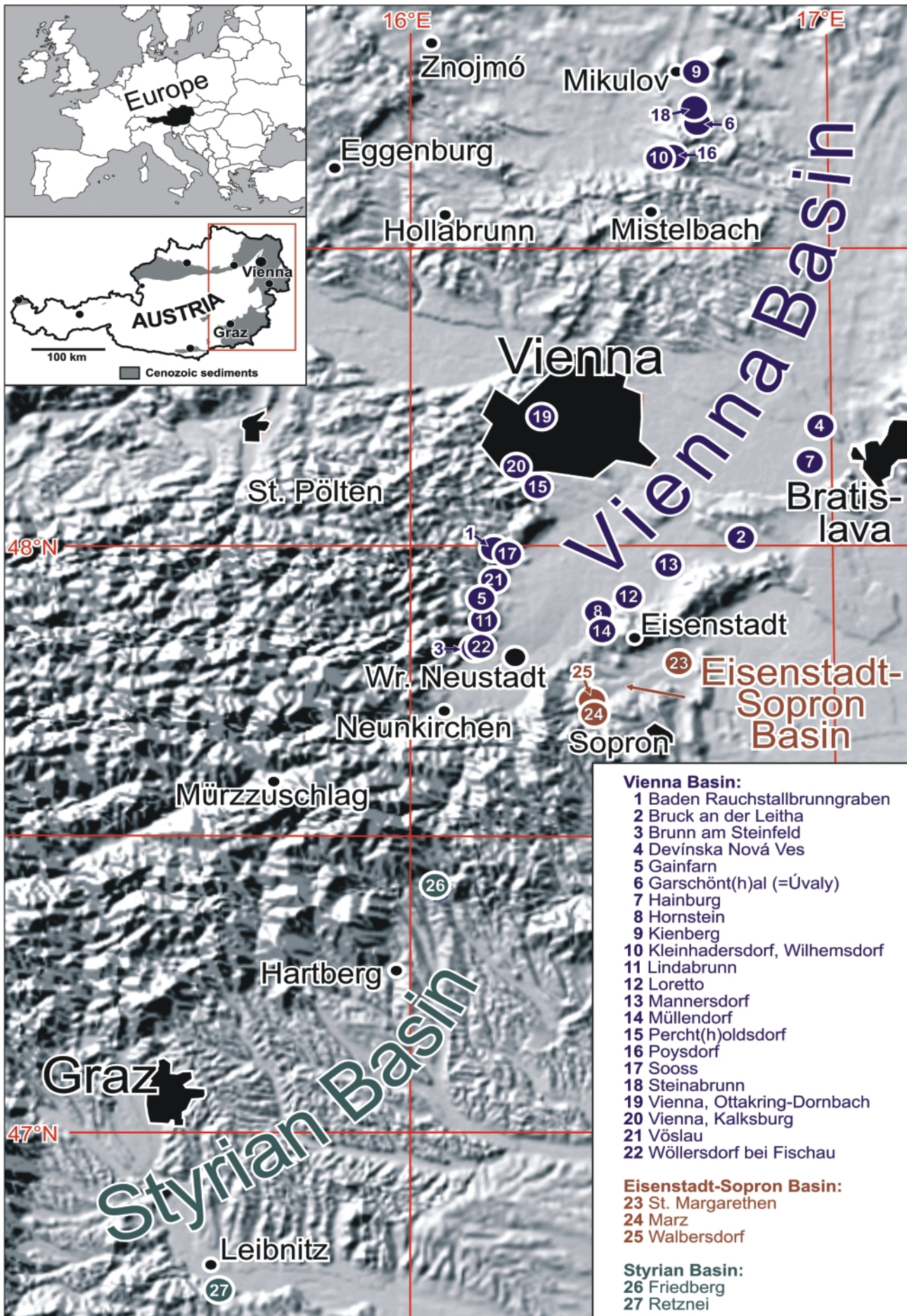
The Miocene fossil record of sirenians in Central Europe is somewhat limited, but it has been studied for more than a century and a half and has occasioned a substantial body of descriptive literature. This literature, unfortunately, applies to the fossils a confusing and largely outdated array of taxonomic names, and presents little coherent paleozoogeographic, phylogenetic, or evolutionary pattern. In this paper we report a new occurrence of sirenian fossils in the Vienna Basin, describe additional unpublished material, revise earlier records from this and surrounding areas, and attempt to clarify the Middle Miocene distribution and evolutionary history of sirenians in the central Paratethys.

In an earlier paper Domning and Pervesler (2001) reviewed Central European sirenian records from the later Early Miocene (Eggenburgian-Ottngangian), showing that all could be referred to the single species *Metaxytherium krahuletzii* Depéret,

1895 (Dugongidae: Halitheriinae), which was originally described and is still best known from Austria. This species is the earliest Old World representative of *Metaxytherium* Christol, 1840, and the progenitor of a Miocene-Pliocene series of chronospecies distributed from Europe to North Africa (Domning and Thomas, 1987; Carone and Domning, 2007; Bianucci et al., 2008; Sorbi et al., 2012), which also comprises almost all of the Neogene sirenians known from that region.

In 2006 a partial skeleton of *Metaxytherium* was discovered in Middle Miocene (Badenian) deposits at Gainfarn in the Vienna Basin of Austria. The description of this specimen gives us the opportunity to extend our earlier study into the Middle Miocene, by reviewing the fossil record of other sirenians of that age in the same general region of Europe, and addressing the unresolved question of the validity of the nominal taxon *Thalattosiren petersi* (Abel, 1904) Sickenberg, 1928.

The sirenian Metaxytherium (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe





Abbreviations: BLLM = Burgenlandisches Landesmuseum, Eisenstadt, Austria; BMNH = Natural History Museum, London, UK; GBAW = Geologische Bundesanstalt, Vienna, Austria; GITUW = Geologisches Institut, Technische Universität (formerly Technische Hochschule), Vienna, Austria; IPUW = Institut für Paläontologie, University of Vienna, Austria; IPUWRG = Ritter-Gulder collection in IPUW; IPUWWF = Weinfurter collection in IPUW; IPUWZA = Zapfe collection in IPUW; KÜH = collection from Kühnring in the Krahuletz-Museum, Eggenburg, Austria (KÜH 88 is on indefinite loan for display at the Steinmetzhaus Zogelsdorf, Zogelsdorf, Austria), LPB = Laboratoire de Paléontologie, Université de Bretagne Occidentale, Brest, France; MAFI = Hungarian Geological Institute, Budapest, Hungary; MNHN = Muséum National d'Histoire Naturelle, Paris, France; MPUN = Museo di Paleontologia dell'Università di Napoli, Italy; NHMBs = Natural History Museum, Basel, Switzerland; NHMW = Naturhistorisches Museum, Vienna, Austria; NOELM = Niederösterreichisches Landesmuseum, St. Pölten, Lower Austria; PS = specimen listed by Pia and Sickenberg (1934); SK = S. Karrer collection in NHMW; STMBV = Stadtmuseum Bad Vöslau, Lower Austria; TH = Technische Hochschule, Wien; USNM = U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

In reference to cheek teeth: L = crown length, AW = anterior width, PW = posterior width, W = total width.

In reference to morphological character states: c. = character state as described and numbered by Domning (1994a), Bajpai and Domning (1997), or Domning and Aguilera (2008); e.g., c. 3(1) refers to state one of character three.

## 2. GEOLOGICAL SETTING

### 2.1 VIENNA BASIN

The Vienna Basin (Fig. 1) constitutes a classical area of geological and palaeontological investigations of Miocene strata. The basin comprises a structurally complex pull-apart basin at the junction of the Eastern Alps and the Western Carpathians (e.g. Wessely, 1988; Decker and Peresson, 1996; Hamilton et al., 2000; Sabol and Kováč, 2006). The structural evolution of the Vienna Basin is characterized by successive phases of compression, strike-slip movements and extension, related to compression and lateral extrusion within the Eastern Alps (Ratschbacher et al., 1991; Decker and Peresson, 1996; Strauss et al., 2006).

In general, the evolution of the Vienna Basin started during the Early Miocene (Eggenburgian-Ottományian-Karpatian) with the development of a partly non-marine piggyback basin on top of Alpine thrusts to the northeast of Vienna (Kováč et al., 1999; Hamilton et al., 2000). Sinistral transtension during the Early and Middle Miocene led to the formation of small-scale, rapidly subsiding lows and relatively stable highs during the

Badenian and Sarmatian. A renewed marine transgression started in the early Badenian and reached the southern part of the basin. Up to 3000 m-thick successions of marls and sandstones characterize the central parts of the basin, whereas delta sands and carbonates were deposited at the basin margins or at shallow depths (Sauer et al., 1992; Weissenböck, 1996; Seifert, 1996). During Sarmatian and Pannonian times, salinity oscillated and finally decreased, leading to limnic-fluvial deposits (Harzhauser and Piller, 2004a, 2004b).

The western margin of the southern Vienna Basin shows large normal or oblique faults that displace marginal sediments such as deltaic deposits and shallow-marine limestone (Leithakalk) against fine-grained basin strata ("Tegel"). In the old Sooss brickyard, faults have been visible that displace Badenian against Sarmatian strata (Rögl et al., 2008).

Due to the lack of good outcrops, detailed sedimentological and palaeontological investigations are restricted to a few natural outcrops and a handful of active pits and exploration drillings.

The oil industry (mainly OMV) and several research projects (e.g. Decker et al., 2005; Hinsch et al., 2005) gathered a wealth of data for the Vienna Basin. The Sooss scientific borehole (FWF project P13743-BIO) penetrated a succession of early Badenian (Langhian, Middle Miocene) sediments, starting from the type section of the Badenian, the old Baden-Sooss brickyard near Baden (Hohenegger et al., 2008, 2009; Pervesler et al., 2008; Wagreeich et al., 2008). Papp et al. (1978) published detailed descriptions of the Badenian stratotype.

The beginning of the Paratethyan Badenian stage approximately coincides with the beginning of the Langhian stage (Fig. 2; Hohenegger and Wagreeich, 2012). The subdivision of the Badenian into the Moravian (lower Badenian), Wielician (middle Badenian) and Kosovian (upper Badenian) reflects the subdivision in the Vienna Basin based on benthic foraminifera into the "Lagenidae Zone", the "*Spiroplectamina* Zone" and the "*Bulimina/Bolivina* Zone". Most characteristic are the widespread evaporites of the Wielician in the Carpathian Foredeep and the Transylvanian Basin. According to this subdivision, the beginning of the Kosovian coincides with the Serravallian stage.

The lithostratigraphic division of the Badenian sediments in the Austrian part of the basin is still under debate. The recent lithostratigraphic chart of Austria (Piller et al., 2004) places these deposits of the classical "Badener Tegel" into the Baden Group, which can be subdivided into the Jakubov Formation and the Lanžhot Formation in the Slovakian part of the basin. The lower part of the Badenian with the Sooss borehole correlates to the Lanžhot Formation (e.g. Kováč et al., 2004).

Based on biostratigraphic data, the succession at the Sooss brickyard can be correlated to the lowermost sequence of the Badenian, sequence VB 5 or Ba1, which is dated as Lower Lagenid Zone and parts of the Upper Lagenid Zone (Kováč et al., 2004; Strauss et al., 2006). The top of this sea-level cycle has been correlated to the global 14.2 Ma hiatus (Strauss et al., 2006) and is associated with a major sealevel drop through-

**FIGURE 1:** Relief map of eastern Austria showing the Vienna Basin, Styrian Basin and Eisenstadt-Sopron Basin with the distribution of Badenian seacow localities.

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe

out the Vienna Basin (e.g. Weissenböck, 1996).

**2.2 EISENSTADT-SOPRON (SUB-)BASIN**

This small basin (Fig. 1), nearly in the shape of an equilateral triangle with side lengths of about 20 km, is a sub-basin of the Vienna Basin. In the north it is limited by the NE-SW trending Leitha Mountains and the associated SE-dipping Eisenstadt fault (Rasser and Harzhauser, 2008). In the east, the basin is limited by the N-S trending Rust faults. The Rust Mountains separate the basin from the Danube Basin in the east. The southern margin in E-W orientation from the Brenner to the Rosalia Mountains is defined by a crystalline ridge, now covered by Lower Miocene gravel. Tectonically and palaeogeographically this relief separates the Eisenstadt-Sopron Basin from the Styrian Basin complex.

During the Early Miocene (Ottangian, Karpatian), terrestrial, lacustrine and fluvial sediments related to the fluvial systems of the southern Vienna Basin were deposited in the Eisenstadt-Sopron Basin. During the Early Badenian the first marine incursion reached the area. Offshore shoal areas with coral

carpets and coralline growth developed during periods of high sea level in the Middle and late Badenian, as the Leitha Mountains were covered by the sea.

A marine seaway between the Eisenstadt-Sopron Basin and the southern Vienna Basin can be supposed in the area of Wiener Neustadt.

**2.3 STYRIAN BASIN**

The Styrian Basin (Fig. 1), which is part of the western Pannonian Basin system, was subdivided by swells into different sub-basins. The main structure, the Middle Styrian Swell, separates the Western from the Eastern Styrian Basin. The basement is formed by the Austroalpine nappe system. Subsidence of the basin, which started during the early Miocene, probably during the Ottangian, was connected with the lateral extrusions of crustal wedges along strike-slip faults towards the Pannonian Basin (Decker and Peresson, 1996; Frisch et al., 2000). A combination of block rotation, subsidence and uplift formed the different sub-basins. Large areas were covered by lava flows during extensive volcanic activity. Extended lignite

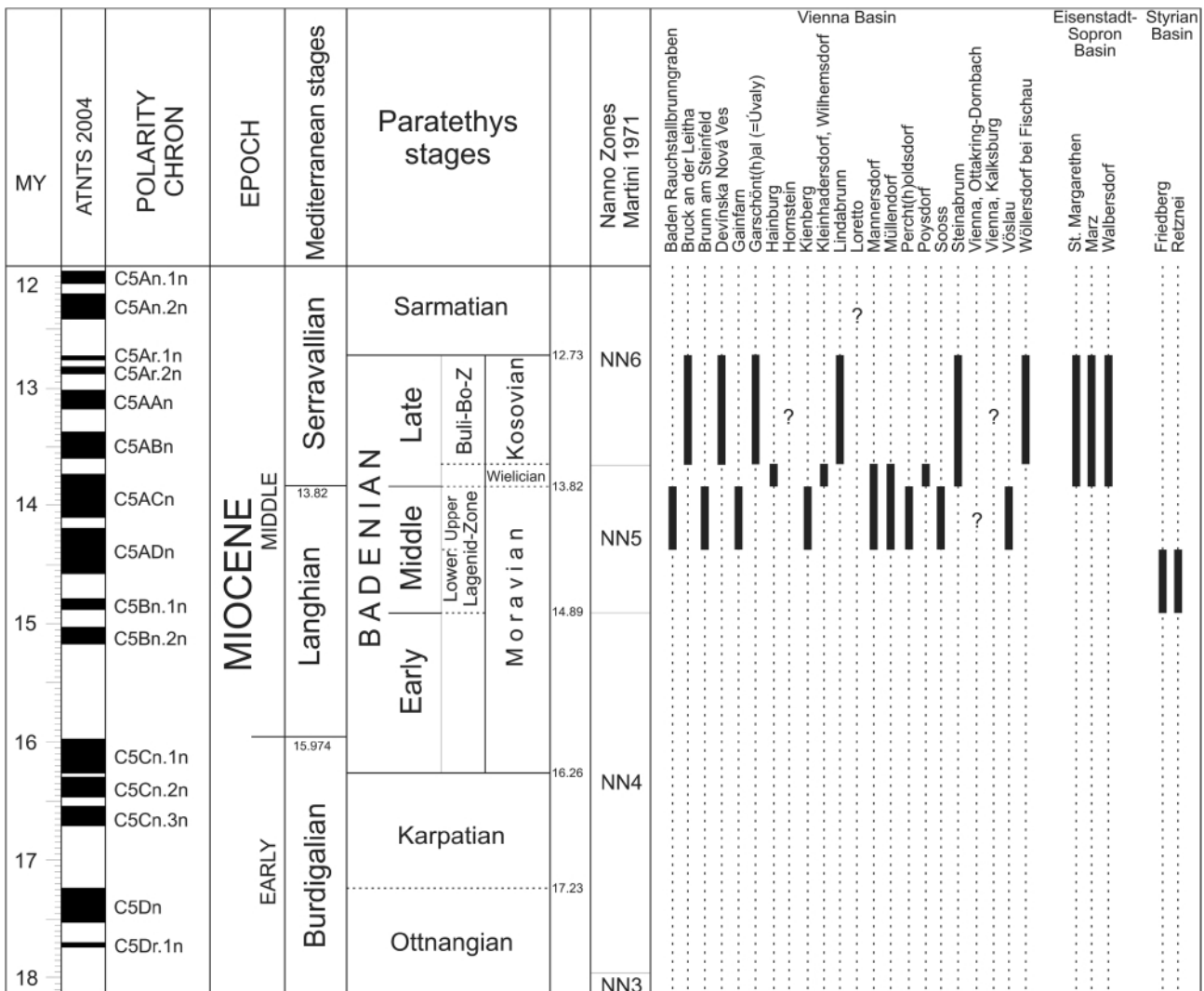


FIGURE 2: Correlation chart of Early and Middle Miocene stratigraphic units (modified after Hohenegger et al., 2011); range of seacow occurrences in the Vienna Basin, Eisenstadt-Sopron Basin and Styrian Basin.



Site # (Fig.1)	Site	Stage	Collection and Catalogue Number	Skeletal Elements	References
<b>Vienna Basin</b>					
1	Baden Rauchstallbrunngraben	late Middle Badenian	NHMW 2007z0106/0001 (cast in USNM)	juvenile skull	This paper
2	Bruck an der Leitha	Late Badenian	Staedt. Mus. Bruck a. d. Leitha (PS 3364)	lower molar fragment	Pia and Sickenberg, 1934
			Staedt. Mus. Bruck a. d. Leitha (PS 3407)	2 rib fragments	Pia and Sickenberg, 1934
3	Brunn am Steinfeld	late Middle Badenian	Staedt. Mus. Wiener Neustadt (PS 3337)	skullcap, endocast, scapula & vertebra fragments, ribs	Pia and Sickenberg, 1934
4	Devínska Nová Ves (=Neudorf an der March)	Late Badenian	NHMW 1857 (PS 3347)	cranial & other fragments	Pia and Sickenberg, 1934
			NHMW 1865 I 1180 (PS 3354)	upper molar fragment	Pia and Sickenberg, 1934
			GBAW (PS 3355)	upper molar fragment	Pia and Sickenberg, 1934
			NHMW 1850 XVI 21 (PS 3360)	left m2 or m3	Peters, 1867: pl. 7, fig. 2; Abel, 1904: pl. 1, fig. 18
			NHMW 1865 I 1181 (PS 3362)	right m3	Peters, 1867: pl. 7, fig. 1
			NHMW 1868 VIII 3 (PS 3365)	lower molar	Pia and Sickenberg, 1934
			NHMW (PS 3375)	vertebra fragment	Pia and Sickenberg, 1934
			GBAW (PS 3378)	"sternum" (misidentified?), vertebra & rib fragments	Pia and Sickenberg, 1934
			NHMW 1906, 1898, & unnum. (PS 3408-3410)	3 rib fragments	Pia and Sickenberg, 1934
			NHMW 1859 V 126, 1854 (PS 3432-3433)	2 juvenile ulnae	Pia and Sickenberg, 1934
			IPUWZA(PS 3717)	caudal vertebra	Pia and Sickenberg, 1934
			IPUWWF (PS 3725)	rib fragment	Pia and Sickenberg, 1934
			IPUWZA (PS 3726)	right humerus	Thenius, 1952: fig. 68
			IPUWZA	stapes, vertebra fragment, left m2, molar fragment	
			IPUW	left m1	
			IPUWRG	left scapula	Thenius, 1952: fig. 69
			NHMW 2012/0156/0001 (Theben-Neudorf; coll. Kornhuber from the TH WIEN)	left M2	
GBAW 2006/18/1, 2355 [in part]	partial skull roof of juvenile	Abel, 1904: 107-108			
NHMW 1997z0178/1984 (PS 3717?)	2 caudal vertebrae	Pia and Sickenberg, 1934			
IPUWWF	juvenile thoracic neural arch				
NHMW 1997z0178/1983, 1985	stapes, vertebra fragment, left m2, molar fragment				
NHMW 862, 1868 VIII 3, and unnum. (PS 1778-1779?)	tooth fragments; same as the "Suide indet." molar fragments listed by Pia and Sickenberg, 1934?	PS 1778-1779 referred to Sirenia by Thenius, 1952: 109			
5	Gainfarn	late Middle Badenian	STMBV/Met/0001	partial skeleton	This paper
6	Garschönt(h)al or Garschental (Úvaly)*	Late Badenian	NHMW 1859 I 13 (PS 3363)	lower molar	Abel, 1904: 110
7	Hainburg an der Donau	early Late Badenian	GBAW Inv. Nr. 2006/18/1 -6 (PS 3331)	skeleton lacking skull; now lost and probably destroyed in World War II except for distal epiphysis of a radius, 2 carpals, 1 metacarpal, 1 phalanx, left innominate, & a cervical vertebra	Peters, 1867: 309-314; pl. 7, figs. 4-8); Abel, 1904: 107-137; figs. 3, 4, 6, 7, 10, 11, 12; pl. 2, fig. 6; pl. 7, fig. 2
			NHMW (PS 3352)	upper incisor [not seen; questionably referred]	Pia and Sickenberg, 1934
8	Homstein	?Late Badenian, ?Sarmatian	NHMW 1970/1396/911 (Fürst Collection #558)	rib fragment	
9	Kienberg (= Kienberk)	late Middle Badenian	GBAW (PS 3421-2)	3 rib fragments	Pia and Sickenberg, 1934
10	Kleinhadersdorf – Wilhelmsdorf	early Late Badenian	IPUWWF	3 rib fragments	
11	Lindabrunn	Late Badenian	Niederöst. Landesmus. St. Pölten (F 5412)	ribs & vertebrae (on exhibition)	
12	Loretto	Sarmatian	NHMW 1890 XX 6 (PS 3412- 3413); NHMW I. a. d. V.A, 18 (PS 3720); NHMW unnumbered	rib fragments	Pia and Sickenberg, 1934
13	Mannersdorf	Late Badenian	NHMW 1850 XXVI 20 (PS 3361)	right m3	Peters, 1867: pl. 7, fig. 3; Abel, 1904: pl. 1, fig. 19
14	Müllendorf	Late Badenian	IPUW	right M2, left m2	
			NHMW 1952/37	left mandible fragment with m3	
			NHMW 1970/1396/910 (Fürst Collection #554)	right rib	
			Gerhard Wanzenböck collection, Gainfarn	fragments of skull, scapula, vertebrae, and ribs of juvenile	This paper
15	Percht(h)oldsdorf	late Middle Badenian	NHMW 1883, C.6123, A2945	3 rib fragments	
			NHMW 1904 (PS 3341)	scapula, humerus, & rib fragments	Pia and Sickenberg, 1934
			NHMW 1886 XVII 48 (PS 3405?)	2 ribs	Pia and Sickenberg, 1934
16	Poysdorf (Poisdorf)	early Late Badenian	GBAW (PS 3403)	rib fragments	Pia and Sickenberg, 1934
17	Sooss	late Middle Badenian	IPUWWF	2 rib fragments	
18	Steinabrunn (=Steinebrunn)	Late Badenian	NHMW 1851 XIII 59 (PS 3398?)	rib	Pia and Sickenberg, 1934
			GBAW (PS 3399)	rib fragments	Pia and Sickenberg, 1934
			NHMW 1851 XIII 60 (PS 3400)	proximal rib fragment	Pia and Sickenberg, 1934

TABLE 1: Fossil sirenian specimens recorded from Middle Miocene (Badenian) deposits of the Vienna Basin and adjacent regions (Central Paratethys).

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe

Site # (Fig.1)	Site	Stage	Collection and Catalogue Number	Skeletal Elements	References
<b>Vienna Basin</b>					
19	Vienna, Ottakring-Dornbach	late Middle Badenian	NHMW 1885 (PS, 3367)	subadult skeleton comprising the "mounted skeleton" (sternum, 12 vertebrae, 32 pairs of ribs) (Wolf sandpit)	Abel, 1904: 108, 131-133
			NHMW 1885 (PS 3350, 3368)	immature skeleton comprising right mandible with ?m2, vertebrae & 23 ribs (Baumann sandpit)	Abel, 1904: 133
			NHMW 1908 103 (PS 3374)	caudal vertebra ("Sandstaette in der Kipflingstrasse")	Pia and Sickenberg, 1934
20	Vienna, Kalksburg	?Late Badenian	IPUW (PS 3342)	partial skeleton, including humerus, partial radius, & ribs	Abel, 1904: 121, pl. 4, fig. 5
			IPUW (PS 3370)	thoracic vertebra & lumbar vertebra	Pia and Sickenberg, 1934
			IPUWWF	rib fragments	
			GITUW (PS 3406)	rib fragments	Pia and Sickenberg, 1934
			NHMW; IPUW?	vertebrae & ribs	Abel, 1904: 106-107
21	Vöslau	late Middle Badenian	NHMW 1935 II 54, SK 4874	rib	
			?	thoracic vertebra	Abel, 1904: 105
			K.F.J. Mus. Baden (PS 3415)	rib fragments	Pia and Sickenberg, 1934
22	Wöllersdorf bei Fischau	Late Badenian	IPUWZA (PS 3724)	rib fragment	Pia and Sickenberg, 1934
			NHMW 1897 (PS 3358)	left m3	Abel, 1904: pl. 1, fig. 17
<b>Eisenstadt-Sopron Basin</b>					
23	St. Margarethen	Late Badenian	BLLM 32816 (Inv. Nr. 3972 - 3983, 4570, 7309, 7310) (PS 3332)	nearly complete skull with scapula, vertebrae including atlas, & ribs of an immature animal	Sickenberg, 1928: 293-323; figs. 1-6; pls. 1-2
			BLLM 32815 (locality uncertain)	adult braincase	This paper
24	Marz (= Márczfalva-Péherko-bánya)	early Late Badenian	MAFI Ob-3036, Ob-3995-3996, Ob-3037, Ob-3039, Ob-3040	left & right humeri, right radius-ulna, 2 metacarpals, right m3 (all seem to have represented the same individual, of which the skullcap, other molars, 6 vertebrae, & some ribs were apparently also collected)	Schréter, 1917
25	Walbersdorf	early Late Badenian	NHMW 1938 No. 38, SK 4879	2 rib fragments	
<b>Styrian Basin</b>					
26	Friedberg	?Early to Middle Badenian	GBAW Inv. Nr. 1927/01/7 -8 (PS 3338)	skullcap fragment & 5 rib fragments	Ehrenberg, 1927: 105
27	Retznei	early Middle Badenian	Gerhard Wanzenböck collection, Gainfarn	skullcap with frontals & supraoccipital	This paper
<b>Pannonian Basin</b>					
	Fazekasboda, Hungary	Late Badenian	MAFI unnumbered	juvenile partial skull, right mandible, left DP4-M1, right dp4-m1, partial atlas, 5 or more thoracic neural arches, & 10 or more ribs	This paper

TABLE 1 CONTINUED

formation occurred in the Western Styrian Basin during the Early and early Middle Miocene, on top of coarse-grained fan deposits. The Paratethys Sea flooded the Western Styrian Basin during the Karpatian (Hohenegger et al., 2009). The Karpatian/Badenian boundary is marked by angular unconformities and sedimentation gaps (Styrian Unconformity). A series of marine transgressions of the Badenian Sea followed on top of the Karpatian deep-water sediments (the Steirischer Schlier). In the Styrian Basin, the transgressions reached their greatest extent in the Early Badenian. The correlation of calcareous nannoplankton and planktonic foraminiferal events between the Styrian Basin and the Mediterranean demonstrates similarities caused by marine connections (Hohenegger et al., 2009).

### 3. SELECTED SIRENIAN LOCALITIES OF BADENIAN (LANGHIAN AND EARLY SERRAVALLIAN) AGE IN THE VIENNA, EISENSTADT-SOPRON AND STYRIAN BASINS: STRATIGRAPHY, AGE, ENVIRONMENTAL CHARACTERISTICS AND TAPHONOMY.

Numerous specimens of seacow fossils were collected in a period of intensified construction activities in the final years of the Austro-Hungarian Empire. Growing urban centers required

construction material like stones and bricks; new railways needed tunnels and cuttings. Need of water supply for growing cities caused the creation of aqueducts. Human power was an important factor in this period and fossils were not always destroyed by mechanical excavation. Countless fossil-bearing localities got lost in the last 100 years and the reconstruction of their coordinates is sometimes only an approximation based on old literature.

In the following description of localities, some of which are indicated in Figs. 1 and 2, three marine basins of Badenian (Middle Miocene) age, inhabited by the seacow *Metaxytherium*, are distinguished. The sirenian remains recorded from these localities are listed in Table 1.

#### 3.1 VIENNA BASIN

##### 3.1.1 BADEN RAUCHSTALLBRUNNENGRABEN, LOWER AUSTRIA

Quarries SSW of Baden; 16°11.94'E, 47°59.94'N (Fig. 1, #1) (Baden Group, Leitha limestone, Baden conglomerate, late Middle Badenian).

South of the road from Baden to the "Gasthof Jägerhaus", two levels of abandoned quarries can still be visited, although



they are becoming more and more overgrown by trees. Within the 60 meters of sediments exposed in these outcrops, a variety of near-shore deposits are developed. The sediments are time equivalents of the pelitic facies in the center of the Vienna Basin.

In the deeper quarry, the “Bryozoenmergel” represents a quieter environment of deposition with not too much wave or current energy. The upper quarries with medium sandstones, fine conglomerates, and coarse sandy limestone with irregular sea urchins (*Clypeaster*) and the trace fossil *Teredolites* represent a higher-energy environment. The following 250 cm-thick bioturbated layer of fine sand and sandy marl contains foraminifers (*Ammonia beccarii* and *Elphidium crispum*), ostracods and clypeasterids. From this layer originates the skull of a juvenile *Metaxytherium*.

The section continues with 5 meters of cross-bedded conglomerates (deltaic sedimentation) inclined toward the center of the basin. The section finishes with marly coralline limestone (Piller and Vávra, 1991).

### 3.1.2 BRUCK AN DER LEITHA, LOWER AUSTRIA

Two quarries on the northern flank of the Spittelberg (=Spitalberg), 0.5 km south of train station Bruck an der Leitha; 16°46.961'E, 48°0.794'N (Fig. 1, #2)

(Baden Group, Leitha limestone, ?late Badenian)

### 3.1.3 DEVÍNSKA NOVÁ VES (=NEUDORF AN DER MARCH), SLOVAKIA

Sandberg locality; 16°58.66'E, 48°12.084'N (Fig. 1, #4)

(Baden Group, Sandberg Member, late Badenian)

Mesozoic limestone (layer 1 in Švagrovský, 1978) is covered by Neogene coarse quartz sand with intercalated gravel horizons (layer 3). The following cross-laminated fine sand layer contains vertebrate fossils (layer 4). The top of the section is formed by further coarser sand layers, carbonate sandstone rich in molluscs and coralline algae (layers 5 and 6). The section is covered by alluvial gravel.

The vertebrate fauna is dominated by teeth, fin rays, vertebrae and otoliths of fishes. Reptiles like sea turtles (*Psephophorus polygonus*) are rare. Several examples of seal and seacow remains are reported from this section. Many of the seacow bones seem to have gotten abraded during taphonomic processes. Wind erosion was proposed by Thenius (1952), but similar appearance of bone shapes was found in specimens of *Metaxytherium krahuletzii* from the Eggenburgian area deposited under water cover (Pervesler et al., 1995; Pervesler et al., 1996; Pervesler et al., 1998; Domning and Pervesler, 2001), and in sirenian specimens from several other parts of the world (Domning, unpublished).

Sedimentology and faunal composition support a near-shore interpretation with periods of higher hydrodynamic energy. That

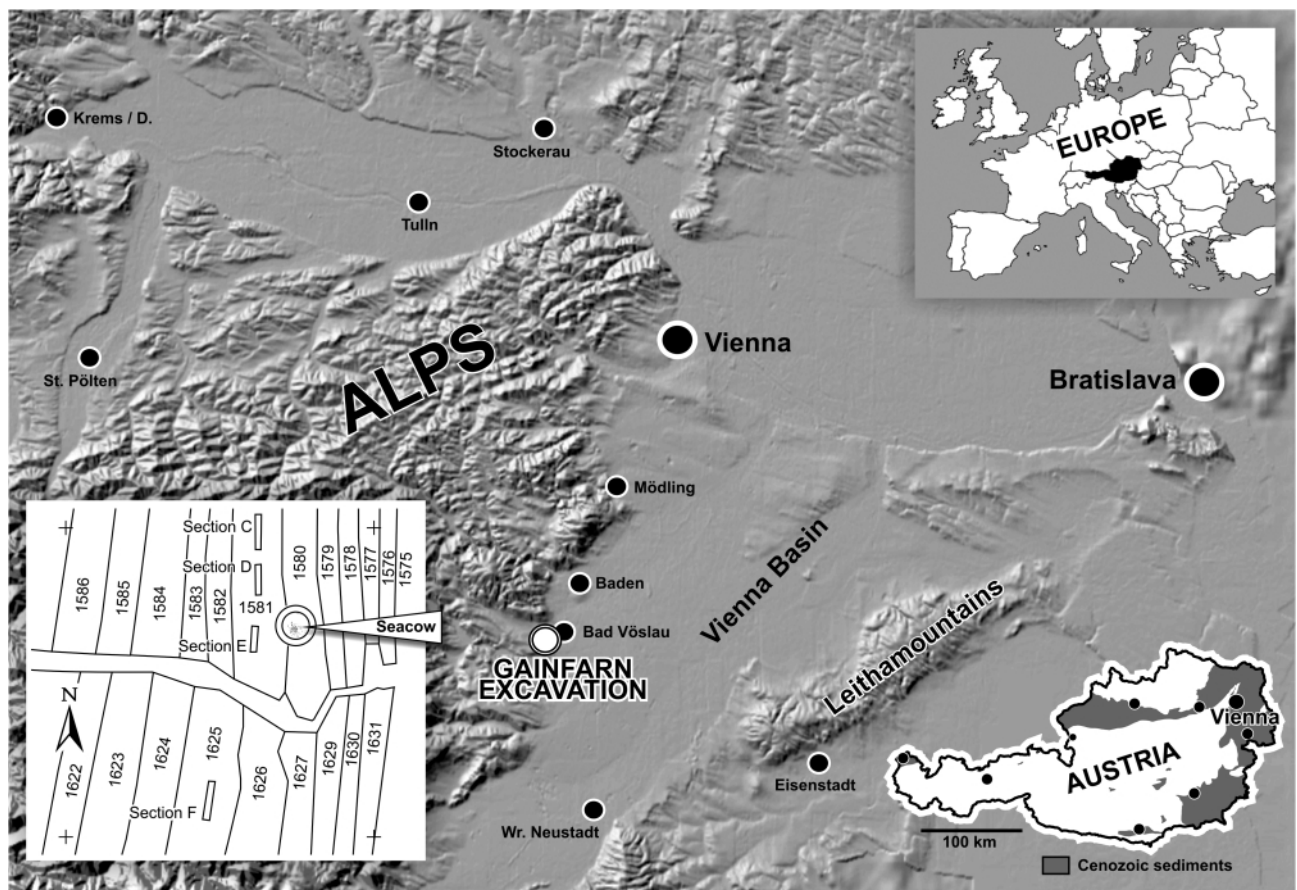
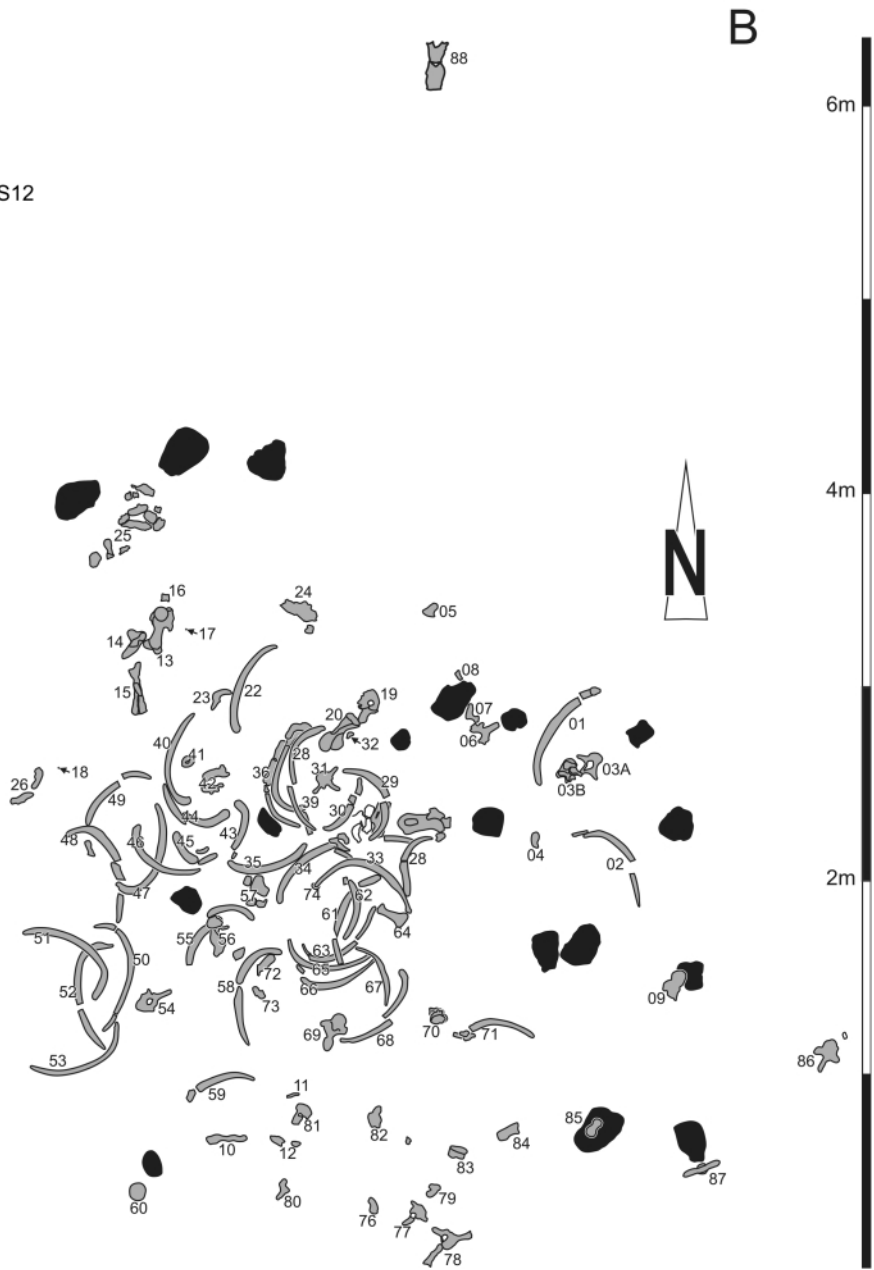
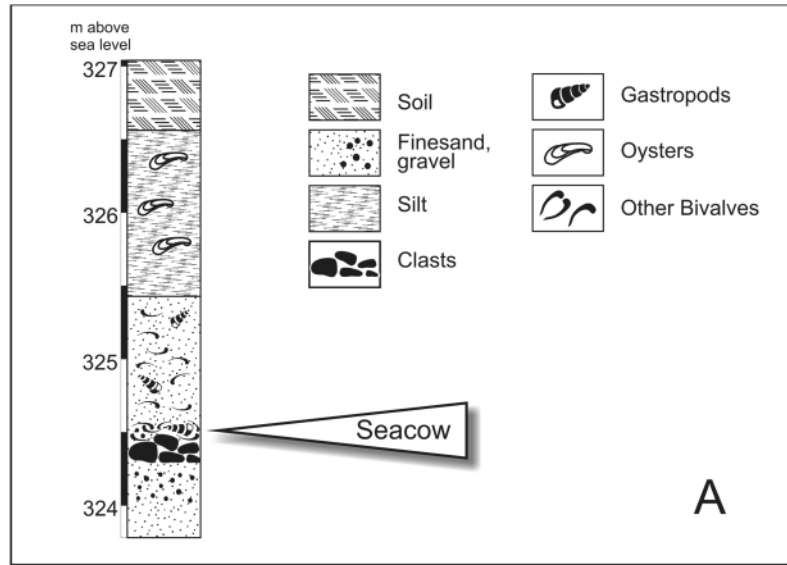


FIGURE 3: Location of the excavation area near Gainfarn (Vienna Basin) with the position of skeletal parts shown in the cadastral map. Sections C, D, E and F correspond to Zuschin et al., 2007.

The sirenian Metaxytherium (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe

- 01-rib
- 02-rib
- 003A-vertebra thoracic
- 03B-vertebra thoracic
- 04-?
- 05-neural arch
- 06-neural arch
- 07-vertebra cervical
- 08-vertebra cervical neural arch fragment [glued to 7]
- 09-vertebra thoracic
- 10-innominate R
- 11-?femur R
- 12-transverse process lumbar?
- 13-humerus R
- 14-squamosal L
- 15-radius-ulna R
- 16-tooth m3 L
- 17-bone indet.
- 18-tooth M1 R
- 19-vertebra thoracic
- 20-humerus L
- 21-?
- 22-rib
- 23-jugal L
- 24-scapula L
- 25-scapula R
- 26-rib?
- 27-rib
- 28-rib
- 29-rib
- 30-rib
- 31 -vertebra
- 32-?
- 33 -rib
- 34-rib
- 35-rib
- 36-rib?
- 37-mandibles L & R, vertebrae cervical & thoracic, ribs, etc.
- 38-vertebra cervical 2 (axis)
- 39-manubrium, rib L1
- 40-rib
- 41-?
- 42-vertebra thoracic
- 43-rib
- 44-rib
- 45-rib?
- 46-rib
- 47-rib
- 48-rib
- 49-rib
- 50-rib
- 51-rib
- 52-rib
- 53-rib
- 54-vertebra thoracic
- 55-rib R3?
- 56-neural arch
- 57-vertebra thoracic; 3 rib sections
- 58-rib R
- 59-rib L
- 60-vertebra
- 61-rib
- 62-rib
- 63-rib
- 64-xiphisternum
- 65-rib
- 66-rib
- 67-rib
- 68-rib
- 69-vertebra thoracic
- 70-vertebra
- 71-rib L
- 72-neural arch
- 73-transverse process lumbar?
- 74-rib?
- 75-?
- 76-neural spine
- 77-vertebra caudal
- 78-vertebra sacral
- 79-?
- 80-neural arch
- 81-vertebra caudal
- 82-vertebra caudal
- 83-vertebra caudal
- 84-vertebra caudal
- 85-bone fragments + S12
- 86-vertebra thoracic
- 87-vertebra lumbar
- 88-braincase
- 89-squamosal R





**FIGURE 4:** A: Sedimentary profile with position of the seacow skeleton (STMBV/Met/0001) on top of a clast layer. B: Distribution of associated skeletal parts deposited in a supine position.

could also explain the generally disarticulated or dissociated occurrence of vertebrate remains.

### 3.1.4 GAINFARN, LOWER AUSTRIA

Excavation area in farmland on the north slope of the "Veitinger Gebirge" south of the village of Gainfarn; 16°11'E, 47°56.72'N (Fig. 1, #5)

(Baden Group, late Middle Badenian)

Seven trenches were excavated in the farmland about 1.3 km south of the village of Gainfarn (Fig. 3) during a university field course in the year 2000. The purpose was the study of fine-scale palaeocommunity dynamics (Zuschin et al., 2007). The first evidence of fossil seacows in Gainfarn was a scapula (IPUW 1007) found in section D approximately 321 meters above sea level.

In 2006 the private collector Gerhard Wanzenböck from Gainfarn made an important seacow discovery. The subsequent scientific excavation by the Department of Palaeontology of the University of Vienna yielded an associated but disarticulated, rather complete skeleton of a mature seacow position-

ned on top of a clast layer (sampling level E2 in Zuschin et al., 2007) at around 326 meters above sea level (Figs. 4, 5). The stratigraphic position of the seacow layer is late Langhian (late Middle Badenian). The sequence stratigraphic framework of the section is made up of three fully marine depositional units, which consist of siliciclastic, pelitic, and sandy to gravelly shallow-water deposits. The marine benthic faunas in this succession primarily occur as autochthonous and storm-influenced, level-bottom assemblages (Zuschin et al., 2007).

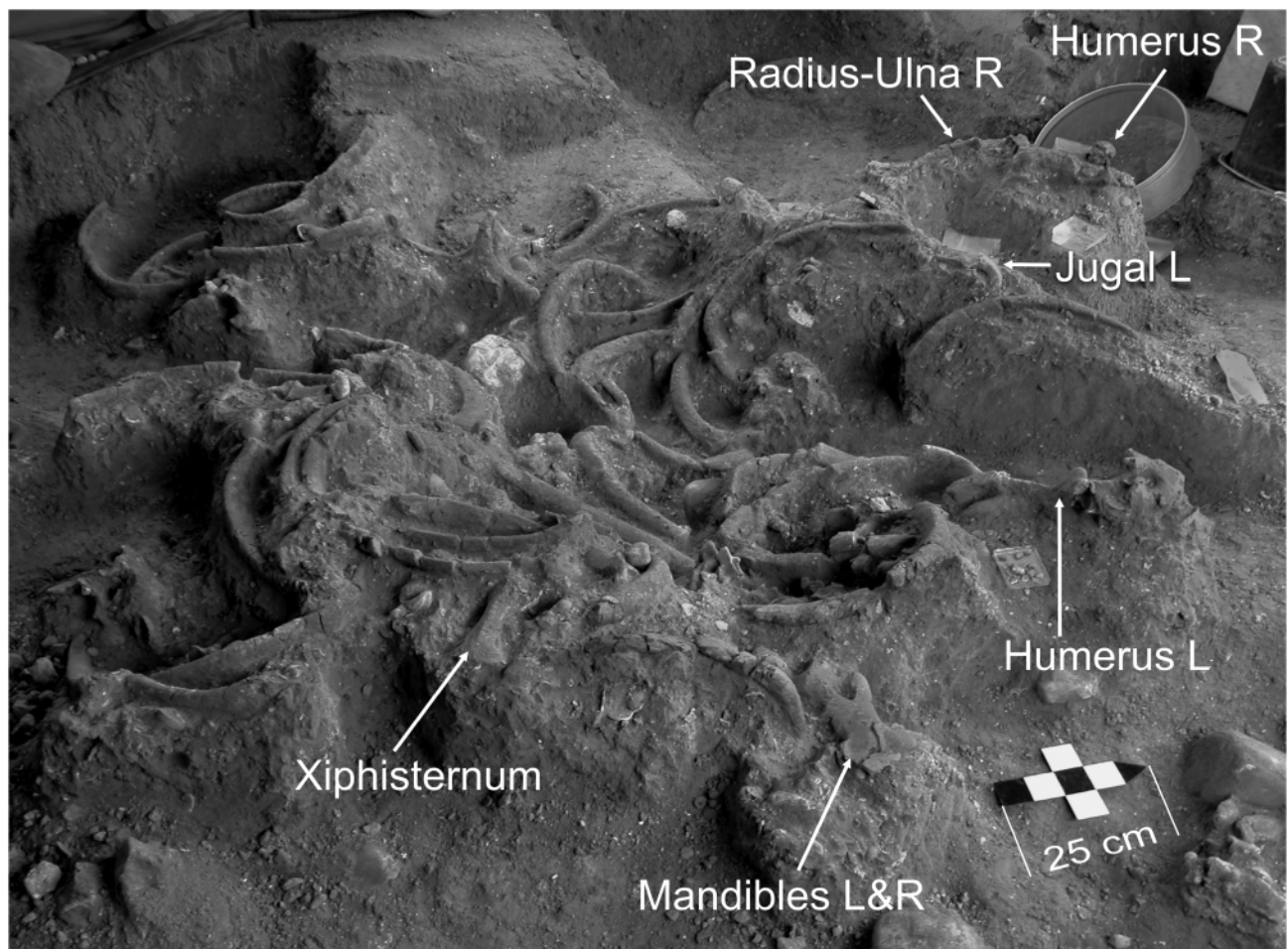
The skeleton (STMBV/Met/0001, described below) was found in supine position, dispersed over an area of more than 16 m<sup>2</sup>. Cervical vertebrae, a great number of thoracic vertebrae, the sacral vertebra and some caudal vertebrae, most of the ribs, fragments of sternum and shoulder blades, both humeri, both forearms, pelvis, femur, and the mandibles were located within this bone cluster. The isolated skull was found at a distance of around 4 meters from the center of the bone accumulation (Fig. 4B).

The skeleton is on exhibition in the Museum of Bad Vöslau.

### 3.1.5 GARSCHÖNTHAL = GARSCHENTHAL

(= Úvaly, Czech Republic), 4 km W of Feldsberg (= Valtice, Czech Republic)

Quarry; ?16°40.832'E, 48°44.837'N (Fig. 1, #6)



**FIGURE 5:** View of seacow skeleton (Gainfarn specimen, STMBV/Met/0001) in the course of excavation.

(Baden Group, Leitha limestone, late Badenian)

Moritz Hörnes (1848) mentions fossils collected by Joseph Poppelack (architect of Prince Liechtenstein in Feldsberg) from the Leitha limestone of Garschenthal (between Feldsberg and Steinabrunn): "A tooth of *Halianassa collinii*, Meyer (remains of which have hitherto been found only in the tertiary sand of Linz and in the millstone-molasse of Wallsee), teeth of *Oxyrhina xyphodon*, Ag., *O. desorii*, Ag., *Galeus aduncus*, Ag., *Lamna elegans*, Ag. and *Myliobates haidingeri*, Münster".

Several quarries in the Leitha limestone still are recognizable in a N-S oriented low mountain ridge now situated at the Austria-Czech border (Veitsberg). These localities lie more or less halfway between Steinebrunn (= Steinabrunn) and Garschenthal (= Garschönthal = Úvaly). The exact locality of the *Metaxytherium petersi* tooth mentioned by Abel (1904): "The k.k. Naturhistorische Hofmuseum in Vienna has in its possession an anterior left molar from the lower jaw of *Metaxytherium* from Garschenthal near Feldsberg in Lower Austria", cannot be determined.

### 3.1.6 HAINBURG AN DER DONAU, LOWER AUSTRIA

Former sandpit; 16° 56.685'E, 48° 8.509'N (Fig. 1, #7)

(Baden Group, late Badenian).

A nearly complete seacow skeleton lacking the skull was found at the end of the 19<sup>th</sup> century in a quarry close to the "Kadettenschule" of Hainburg. Stache (1867) described the section of the quarry to the west of the castle hill of Hainburg. The skeleton was stored in the "k.k. Geologischen Reichsanstalt" (Survey) and destroyed to a large extent by bombing in World War II. It is still possible to determine the location of the quarry despite the houses built in its area (houses Steinbruchweg 6 and 12, southwest of the Schlossberg). It is also possible to recognize Stache's description in the field, with sands and sandstones at the base of the section followed by coarser conglomeratic sandstones and the rock face composed of quartz conglomerate behind the grave of Juliana von Schickler (Stache's "Grab der Engländerin"). The locality of the seacow may be slightly below the lowermost outcropping sandstone layers.

The skeleton was found embedded supine in a sandstone layer with its vertebral column, ribs and most of the other bones sticking up into the overlying layer of loose sand. The skull was possibly lost during work in the quarry, or isolated by taphonomic processes before deposition of the skeleton (Hauer, 1867; Stache, 1867; Abel, 1904). It became the holotype of *Metaxytherium petersi* Abel, 1904.

### 3.1.7 LINDABRUNN, LOWER AUSTRIA

Quarries in conglomerate; 16°9.873'E, 47°54.895'N (Fig. 1, #11)

(Baden Group, Lindabrunn conglomerate, late Badenian)

Two quarries located southwest of the village of Enzesfeld at the western margin of the southern Vienna Basin show two coarsening-upward sequences containing silty arenites to coarse-grained conglomerates (Rabeder, 2001).

Sedimentary structures as well as biofacies and lithofacies point to a transition from marine-dominated environments in the lower part of the outcrops to brackish and fluvial environments in the upper part. The Lindabrunn Conglomerate can be described as a fan delta with delta plain, delta front and prodelta. The sandy parts of the outcrops contain foraminifera, bivalves, spines of sea urchins and trace fossils (*Ophiomorpha*); the conglomerates contain tusks of proboscideans and bones of seacows (*Metaxytherium*).

### 3.1.8 MANNERSDORF, LOWER AUSTRIA

Quarries; 16°36.639'E, 47°58.085'N (Fig. 1, #13)

(Baden Group, Leitha limestone, late Middle Badenian).

A recently published paper (Wiedl et al., 2012) on the Mannersdorf quarries at the northeastern edge of the Leitha Mountains (Lower Austria) concentrates on the tectonic phases of this Badenian carbonate platform in the Vienna Basin. At the beginning stands a marine transgression with the development of a coastal slope scree and subsequent prograding of a Gilbert-type fan delta, overlain by very heterogeneous coralline limestones. Coralline limestones indicate shallow-water environments (i.e., seagrass meadows).

Other parts of the quarry area show a rapid facies change from relatively deeper environments (i.e., indicated by the abundance of the bivalve *Pholadomya* in-situ) to shallow waters (indicated by corals). Corals are generally rare in the limestones of the Mannersdorf quarries, which represent mostly deeper environments with conspicuous differences in faunal associations.

### 3.1.9 MÜLLENDORF, BURGENLAND, AUSTRIA

(till 1921 Szárazvám, Hungary)

Chalk quarry; 16°27.175'E, 47°51.511'N (Fig. 1, #14)

(Baden Group, Leitha limestone, late Middle Badenian)

Several quarries at the western margin of the Leitha Mountains (Fig. 1, #14) exploited Leitha limestone since around 1870. In the beginning the quarries produced stones, later up to 10 quarries produced quicklime and chalk and covered an extensive area (Tollmann, 1955). The origin of the chalk is weathered Leitha limestone with destruction of fossils to a large extent (Dullo, 1983). Digging of the soft chalk is now done by strip mining; observation of vertical successions is therefore difficult (Piller and Vávra, 1991). Well-preserved oysters and sea urchins as well as strongly weathered corals (*Tarbellastrea reussiana* with diameters of up to 1 meter) are very common. The corals were bored by bivalves such as *Lithophaga* and *Gastrochaena* and by barnacles (*Pyrgoma costatum* [Abel, 1928]).

### 3.1.10 STEINABRUNN (=STEINEBRUNN), LOWER AUSTRIA

Quarries; 16°40.705'E, 48°44.821'N (Fig. 1, #18)

(Baden Group, Leitha limestone, late Badenian)

Several quarries in the Leitha limestone in the N-S oriented low mountain ridge already mentioned in the paragraph on



Garschenthal (= Garschönthal = Úvaly). Now they are situated at the Austria-Czech border (Veitsberg). Fragments of red algae, bryozoans and echinoderms are the main components of this biotrititic packstone to grainstone.

### 3.1.1.1 VIENNA, OTTAKRING, HERNALS, DORN-BACH

Wolf sandpit, Baumann sandpit, ?Kipflingstrasse sandpit (Fig. 1, #19)

(Baden Group, ?Late Middle Badenian)

The k.k. Naturhistorische Hofmuseum excavated 12 vertebrae, 32 ribs, and the sternum of an adult "*Halitherium*" in the Josef Wolf sandpit west of the Dornbacher Strasse (Hauer, 1886: 28). In the neighboring sandpit owned by the jurist Dr. Moritz Baumann, ribs, vertebrae and a right mandible of a juvenile seacow were excavated in the same year from a sand layer higher in position than the Wolf specimen. Both skeletons lacked skulls and limbs (Hauer, 1886: 28). Some confusion concerning these skeletons was introduced by Pia and Sickenberg (1934), who assigned the number PS 3350 to the mandible but mistakenly attributed it to the adult skeleton including the sternum (PS 3367). PS 3350 should have been associated with the immature skeleton PS 3368.

### 3.1.1.2 VIENNA, KALKSBURG

Quarries in Leitha conglomerate and breccia. ?16°14.888'E, 48°8.287'N (Fig. 1, #20)

(Baden Group, ?late Badenian)

Kalksburg was formerly an independent village, but in 1938 it was integrated into Vienna. It belongs now to the 23<sup>rd</sup> district at the southwestern margin of Vienna (Liesing).

Fuchs (1869) mentions a quarry east of Kalksburg, possibly quarry 1 (= Steinbruch 1 in Karrer, 1877) with "Leytha-Conglomerat" (ca. 300 meters east from the parish church in Kalksburg). The quarry had a thickness of around 13 meters (= 42 Fuss) and from base to top was composed of coarse and fine-grained conglomerates, fine sand with *Teredo* and plant fossils, sandstone, hard conglomerate with molluscs and clayey sand. The author lists the fossil content in a table with the categories echinoderms, bivalves, gastropods, foraminifers and "varia" which includes also bones of seacows ("Knochenreste von *Halitherium*"). Already Karrer (1877) notes abandonment of the quarry due to construction of houses nearby.

Abel (1904) mentions seacow remains from Kalksburg discovered by quarry workers in 1896. Probably they came from another quarry around 80 meters further to the east (Quarry 2 in Karrer, 1877). Regrettably, only a humerus and a fragment of the forearm reached the University collection.

## 3.2 EISENSTADT-SOPRON BASIN

### 3.2.1 ST. MARGARETHEN, BURGENLAND, AUSTRIA

Quarries; 16°38.084'E, 47°48.194'N (Fig. 1, #23)

(Baden Group, Leitha limestone, late Badenian)

The location of the quarry named "Steinbruch St. Margare-

then" is not well defined. The coordinates given above describe the center of a vast quarry area between St. Margarethen and the town of Rust, exploited since the first century AD by the Romans. Sickenberg (1927, 1928) describes remains of a seacow found by quarrymen after blasting in the St. Margarethen quarry. No exact information on the position of the discovery or the section is given. The sediment, characterized as calcareous sandstone with a matrix of fragmented calcareous red algae ("Lithothamnienknollen"), contains fragments of oysters, pectinids, and shells of sea urchins. Only cavities and endocasts indicate the existence of aragonitic shells of bivalves like *Glycymeris* and several gastropods. The color of the sediment varies from white to yellowish and brownish near skeletal remains.

Sickenberg restored and studied a relatively complete skeleton after extracting the bones from eight hard calcareous sandstone blocks, which were moved to the Burgenländisches Landesmuseum in Eisenstadt. He found the nearly complete skull (unfortunately the occipital region was damaged), a fragment of the atlas, parts of several other vertebrae, many rib fragments, the left shoulder blade, and other bone fragments.

A braincase (BLLM 32815) was mentioned by Bianucci et al. (2008) as *Metaxytherium* sp. ("BLLM 22816") from Mannersdorf. However, this provenance is apparently incorrect: it is now believed to have come from St. Margarethen, but no other details of its discovery are available. Its gray color differs from that of Sickenberg's specimen (BLLM 32816), which is yellow-brown, indicating a different locality in the St. Margarethen complex. The sandy matrix of BLLM 32815 did not yield any microfossils.

### 3.2.2 MARZ, BURGENLAND, AUSTRIA

(= Márczfalva–Péherkő-bánya, Sopron County, Hungary).

Brickyard; 16°26.148'E, 47°43.2'N (Fig. 1, #24)

(Baden Group, late Badenian)

This locality yielded a partial skeleton of a *Metaxytherium* (Schréter, 1917), of which only limb bones and a tooth now remain.

### 3.2.3 WALBERSDORF, BURGENLAND, AUSTRIA

Brickyard; 16° 25.40'E, 47° 44.34'N (Fig. 1, #25)

(Baden Group, late Badenian)

## 3.3 STYRIAN BASIN

### 3.3.1 FRIEDBERG, STYRIA, AUSTRIA

Hochstraßstunnel; from 16°3.494'E, 47°25.652'N to 16°3.916'E, 47°25.675'N (Fig. 1, #26)

(Tauchen Formation, Karpatian, ?early to Middle Badenian)

During construction of the "Hochstraßstunnel" south of Friedberg (NE Styria), J. Winkler did geological studies between 1924 and 1925 (Winkler, 1927). He reports a clayey bone layer uncovered during tunneling for the railway, which contained marine mammals together with marine bivalves indicating shallow marine deposition. Ehrenberg (1927) identified remains of

rhinoceros, stag, leopard and seacow (*Metaxytherium*).

Recent environmental interpretations of deltaic environments in the Bay of Friedberg-Pinkafeld (Nebert, 1985) do not conflict with the old descriptions.

### 3.3.2 RETZNEI, STYRIA, AUSTRIA

Quarry of cement plant; 15°33.532'E, 46°44.388'N (Fig. 1, #27) (Baden Group, Weissenegg Formation, Lower Lagenidae Zone, early Middle Badenian)

The Lafarge cement quarry of Retznei (southern Styria) comprises Upper Karpatian and Lower Badenian sediments. Only a small 4 m-high outcrop in the middle part of the quarry exhibits the erosive top of the Karpatian overlain by Badenian limestones. The Karpatian sediments ("Steirischer Schlier") consist of dark-gray silty marls with sparse pebbles ("Geröllmergel") from the crystalline basement (Spezzaferri et al., 2002). It contains some mollusc and echinoid debris, and a rich foraminiferal and ostracod fauna. Another pebble layer, containing also large clasts bored by bivalves, forms the base of a huge carbonate buildup.

This buildup starts in the old quarry (cf. Friebe, 1988, 1990) with a small coral reef and extends into coralline limestone of the Weissenegg Formation (Leithakalk). Towards the southeast the limestones show a basinward transition into reworked material of the slope facies. At the top of the buildup, marly sands with tuffitic intercalations terminate the carbonate sedimentation.

Several meters below the tuffitic layer (14.39 ± 0.12 Ma, Handler et al., 2006), a skull roof of a seacow with frontals and supraoccipital was found in early Middle Badenian sediments by the private collector Gerhard Wanzenböck (collection stored in Gainfarn).

## 4. SYSTEMATIC PALEONTOLOGY

Class MAMMALIA Linnaeus, 1758

Order SIRENIA Illiger, 1811

Family DUGONGIDAE Gray, 1821

Subfamily HALITHERIINAE (Carus, 1868) Abel, 1913

Genus *Metaxytherium* Christol, 1840

*Metaxytherium* Christol, 1840, L'Institut Vol. 8, Sect. 1, No. 352: 323. [Type, by subsequent designation (Depéret and Roman, 1920): *Metaxytherium cuvieri* Christol (= *Hippopotamus medius* Desmarest).

*Thalattosiren* Sickenberg, 1928, Denkschr. Akad. Wiss. Wien, Math.-Nat. Kl. 101: 293. [Type, by monotypy: *Metaxytherium petersi* Abel].

For other synonyms, see Domning (1996, 2010).

**Emended Diagnosis.** – A paraphyletic genus of dugongids that differs from most other halitheriines by possession of the following apomorphies: permanent premolars 1-4 lost [c. 157 (2)]; supraorbital process of frontal reduced and dorsoventrally thickened [c. 36(1)]; posterior part of zygomatic-orbital bridge of maxilla usually elevated >1 cm above alveolar margin [c. 11(1)]; nasals usually separated in midline [c. 31(1)];

supraoccipital wider ventrally than dorsally; exoccipitals usually not meeting in a midline suture above foramen magnum [c. 66(1)]; and ventral border of horizontal ramus of mandible strongly concave [c. 122(3)]; differs from hydrodamalines by lack of the following apomorphies: processus retroversus of squamosal uninflected [c. 77(2)]; lacrimal reduced [c. 91(2)]; ventral border of horizontal ramus of mandible moderately concave [c. 122(2)]; horizontal ramus of mandible slender [c. 128(0)]; first upper incisor vestigial or absent [c. 139(1)] (J. Vélez-Juarbe and D. P. Domning, in preparation).

*Metaxytherium medium* (Desmarest, 1822) Hooijer, 1952  
*Hippopotamus medius* Desmarest, 1822, Mammalogie: 388.  
*M[etaxytherium] Cuvierii* (Christol) Christol in Blainville, 1844, Ostéogr., Genre Manatus: 130.

*Halitherium cordieri* Christol, sensu Peters, 1867, Jb. Geol. Reichsanst. Wien 17(2): 309.

*Metaxytherium petersi* Abel, 1904, Abh. K.-K. Geol. Reichsanst. Wien 19(2): 15, 107, June 1904. [Holotype: GBAW Inv. Nr. 2006/18/1-6, skeleton lacking skull; described by Peters (1867: pl. 7, figs. 4-8) and Abel (1904: figs. 3, 4, 6, 7, 10, 11, 12; pl. 2, fig. 6; pl. 7, fig. 2), termed "Typusexemplar" by Pia and Sickenberg (1934: 403, no. 3331); probably destroyed in World War II except for the distal epiphysis of a radius, two carpals, one metacarpal, one phalanx, the left innominate, and a cervical vertebra (GBAW Inv. Nr. 2006/18/1-6, 2350-2355). The radial epiphysis (2354) was not mentioned by Peters (1867), but was briefly described by Abel (1904:122). Abel (1904:133) explained that several elements of the skeleton, including the body of the axis, another cervical vertebra (C3?), and a number of chevron bones, were prepared subsequent to Peters' 1867 publication, although the C3? actually appears in Peters' (1867) plate 7, fig. 4. Of these, only the C3? (2355) survives today. Bearing the same number as this vertebra (2355) is a skullcap fragment, mistakenly associated with this specimen; it is actually from Neudorf an der March and was described by Abel (1904:107-108). Type locality: Hainburg an der Donau, Lower Austria; "Zweite Mediterranstufe"; Baden Group, *Spiroplectamina* Zone [pers. communication, G. Wessely]; Late Badenian.] **NEW SYNONYMY.**  
*Thalattosiren petersi* (Abel) Sickenberg, 1928, Denkschr. Akad. Wiss. Wien, Math.-Nat. Kl. 101: 293.

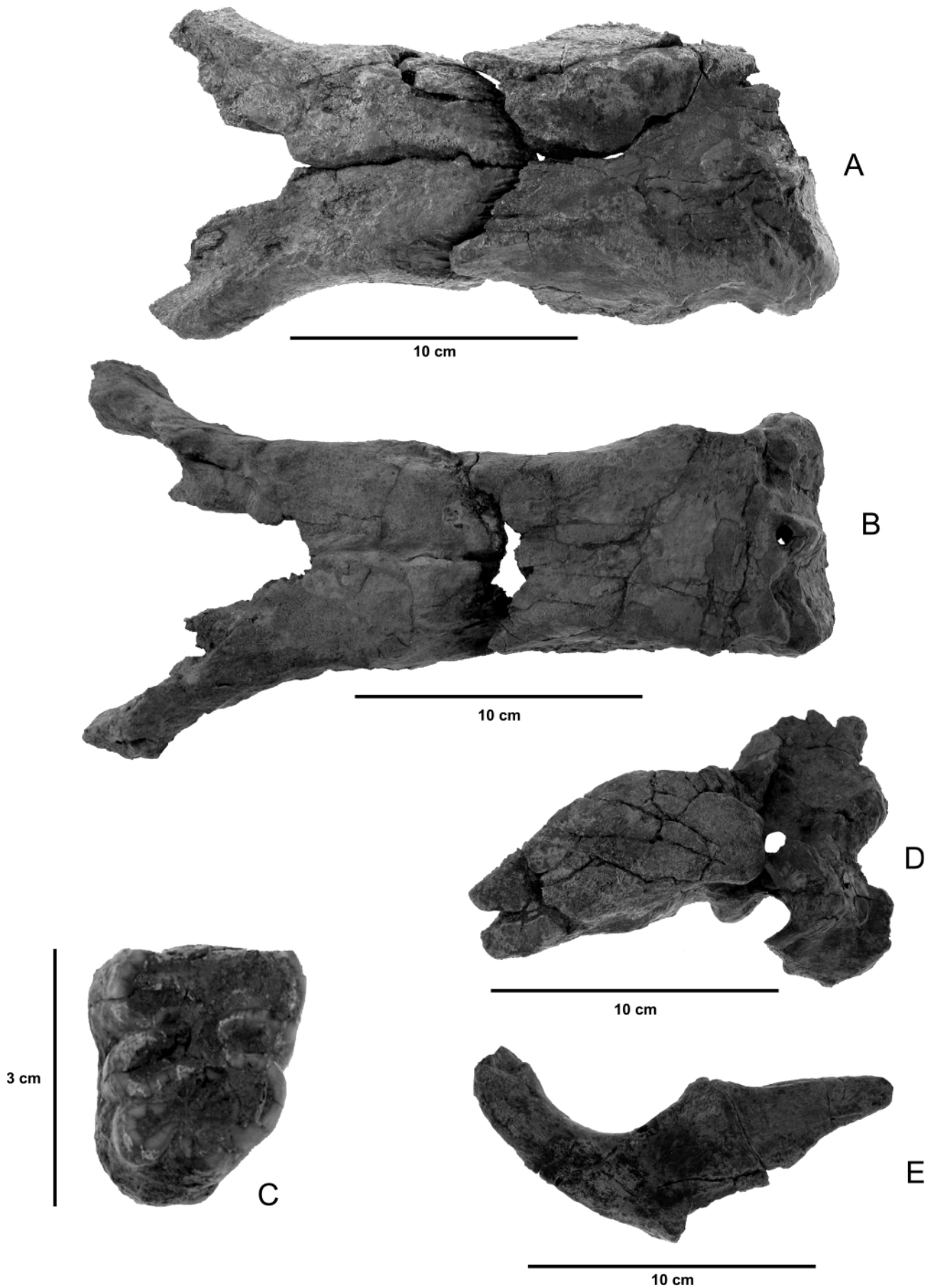
*Metaxytherium medium* (Desmarest) Hooijer, 1952, Osiris 10: 114.

*Metaxytherium catalaunicum* Pilleri in Pilleri, Biosca, and Via, 1989, Tert. Sir. Catalonia: 68. [Holotype: Mus. Vilafranca del Penedès (Barcelona) no. 1210, skull, mandible, and postcranial remains. Type locality: Olèrdola, Catalonia, Spain; upper Burdigalian-Langhian.] Synonymized by Domning, 1996, Smithson. Contr. Paleobiol. 80: 387.

For other synonyms, see Abel (1904: 13-14) and Domning (1996, 2010).

**Emended Diagnosis.** – *Metaxytherium* differing from *M. krahuletzi* by ventral extremity of jugal usually lying fully ventral to orbit [c. 85(2)]; differs from later European species (*M. serresii*,





**FIGURE 6:** *Metaxytherium medium*. A: Braincase (frontals, nasals, parietal, supraoccipital) from the Gainfarn specimen (STMBV/Met/0001), dorsal view (Fig. 4, #88). B: Braincase (frontals, parietal, supraoccipital) from the Retznei specimen, dorsal view. C: left m3 of STMBV/Met/0001, occlusal view (Fig. 4, #16). D: Left squamosal of STMBV/Met/0001, lateral view (Fig. 4, #14). E: Left jugal of STMBV/Met/0001, lateral view (Fig. 4, #23).

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe

ab	Height of jugal below orbit
AH	Length of premaxillary symphysis
BI	Rear of occipital condyles to anterior end of interfrontal suture
CC'	Zygomatic breadth
cc'	Breadth across exoccipitals
de	Top of supraoccipital to ventral sides of occipital condyles
F	Length of frontals, level of tips of supraorbital processes to frontoparietal suture
FF'	Breadth across supraorbital processes
ff'	Breadth across occipital condyles
GG'	Breadth of cranium at frontoparietal suture
gg'	Width of foramen magnum
HI	Length of mesorostral fossa
hi	Height of foramen magnum
KL	Maximum height of rostrum
MM'	Posterior breadth of rostral masticating surface
no	Anteroposterior length of zygomatic-orbital bridge of maxilla
OP	Length of zygomatic process of squamosal
OT	Anterior tip of zygomatic process to rear edge of squamosal below mastoid foramen
P	Length of parietals, frontoparietal suture to rear of external occipital protuberance
QR	Anteroposterior length of root of zygomatic process of squamosal
rr'	Maximum width between labial edges of left and right alveoli
ss'	Breadth across sigmoid ridges of squamosals
ST	Length of cranial portion of squamosal
T	Dorsoventral thickness of zygomatic-orbital bridge
tt'	Anterior breadth of rostral masticating surface
UV	Height of posterior part of cranial portion of squamosal
WX	Dorsoventral breadth of zygomatic process
yy'	Maximum width between pterygoid processes
YZ	Length of jugal
LFr	Length of frontals in midline
LSR	Length of skull roof from anterior end of interfrontal suture to posterior side of external occipital protuberance
LPT	Dorsoventral length of pterygoid process, measured from roof of internal nares
WPI	Minimum width of palate just anterior to tooth row
HSo	Height of supraoccipital
WSo	Width of supraoccipital
RD	Deflection of masticating surface of rostrum from occlusal plane (degrees)

Dimension	Müllendorf (juvenile)	MAFI unnum. [Fazekasboda] (juvenile)	NHMW 2007z0106/0001 (juvenile)	BLLM 32816 (juvenile)	BLLM 32815 (adult)	Retznei (adult)	STMBV Met/0001 [Gainfarn] (old adult)
ab	--	--	--	44	--	--	--
AH	--	--	72+	108+	--	--	--
BI	--	--	--	--	206+	--	--
CC'	--	--	--	187	215	--	--
cc'	--	--	--	--	144	--	--
de	--	--	--	--	121	--	--
F	--	--	--	120e	--	145e	--
FF'	--	--	105	130	100+	145e	--
ff'	--	--	--	--	107	--	--
GG'	55	72e	75	81	68e	70	76
gg'	--	--	--	--	49	--	--
HI	--	--	108e	117e	--	--	--
hi	--	--	--	--	45	--	--
JJ'	--	--	49e	56	--	--	--
KL	--	--	50	68	--	--	--
MM'	--	--	46	46e	--	--	--
no	--	--	23+	--	--	--	32
OP	--	74	--	109e	118+	--	--
OT	--	--	--	--	156+	--	--
P	75	76	--	90	100	105	94
QR	--	38	--	50	62	--	46e
rr'	--	--	--	70	--	--	--
ss'	--	--	--	--	193	--	--
ST	--	--	--	--	101	--	104
T	--	--	7e	9e	--	--	13
tt'	--	--	30e	--	--	--	--
UV	--	--	--	--	96	--	102
WX	--	30	--	41	42	--	49
yy'	--	--	48e	65e	--	--	55e
YZ	--	--	--	137e	--	--	149+
LFr	47e	--	--	64	63+	80e	74
LSR	--	--	--	153*	160+	190e	170e
LPT	--	--	40e	40e	--	--	62+
WPI	--	--	36e	16e	--	--	--
HSo	--	44	--	53	56	56	59
WSo	71	83	--	86	96	86+	90e
RD	--	--	48+	55e	--	--	--

\* 165 mm from anterior end of internasal suture.

*M. subapenninum*) by having a tusk alveolus much less than half the length of the premaxillary symphysis [c. 140(0)].

**Holotype.** – MNHN Fs 2706, partial left mandible with M2-3 and roots of M1 (the "Moyen hippopotame" of Cuvier, 1821).

**Type Locality.** – Saint-Michel en Chaisine, Maine-et-Loire, France.

**Formation.** – Calcareous tuff.

**Age.** – Middle or Late Miocene (Serravallian-Tortonian).

**Range.** – Europe and probably North Africa, with reports from Portugal, Spain, France, The Netherlands, Italy, Austria, Slovakia, Hungary, and Mediterranean islands including Sardinia and Crete. Middle to Late Miocene; Langhian to late (but not latest) Tortonian, approximately MN 5 to MN 11, since only *M. serresii* is recorded from MN 12 (Carone and Domning, 2007).

**Newly Referred Specimens.** – The following previously-undescribed specimens from the Central Paratethys/Vienna Basin are here referred to *M. medium*. The other specimens listed in Table 1 (many of them rib or other fragments not individually diagnostic at the specific or even generic level) may also be presumed to represent this species, in the absence of evidence that another sirenian species is present in these deposits.

Baden, Rauchstallbrunngraben quarry, Lower Austria: NHMW 2007z0106/0001, juvenile skull.

Gainfarn, Lower Austria: STMBV/Met/0001/#1 - #89, partial skeleton.

St. Margarethen (?), Burgenland, Austria: BLLM 32815, braincase. Mentioned by Bianucci et al. (2008) as *Metaxytherium* sp. ("BLLM 22816"), supposedly from Mannersdorf.

**TABLE 2:** Measurements (in mm) of skulls of Badenian *Metaxytherium medium* from the Central Paratethys. Measurements designated by letters are modified from Domning (1988) and earlier works. e = estimated; nm = not measured; + = measurement on incomplete element.

Müllendorf, Burgenland, Austria: Wanzenböck collection, juvenile skull fragments and partial skeleton.

Retznei, Styria: Wanzenböck collection, adult skull roof.

Fazekasboda, Hungary: MAFI unnum., juvenile partial skull, right mandible, left DP4-M1, right dp4-m1, partial atlas, 5 or more thoracic neural arches, and 10 or more ribs.

## 5. DESCRIPTION OF GAINFARN SPECIMEN

(Tables 2-3, 5-10; Figs. 6A, C-E, 7, 8)

The skeleton excavated at Gainfarn in 2006 (STMBV/Met/0001/#1-#89) is that of an old adult (m1 probably lost, m3 moderately to heavily worn) and, judging from the morphology of the pelvis, probably a female. Most parts of the skull, mandibles, and appendicular elements (excepting the manus) are represented, together with at least some vertebrae from each region of the column and many ribs. Also collected at the same site in 2000, a few meters away but at a lower horizon, was an isolated left scapula (Table 7; Zuschin et al., 2007).

The following descriptions also mention for convenience some contrasts with the most complete skull from this region, the juvenile specimen BLLM 32816 (Sickenberg, 1928). For other labeled sketches of the cranial anatomy of *Metaxytherium* and related dugongids, see also Domning (1978:fig. 7) and Sorbi et al. (2012:figs. 5-6).

Premaxilla, Ethmoid, Vomer, Lacrimal, Palatine, Tympanic, Auditory Ossicles, Hyoid Apparatus, Carpals, Metacarpals, Phalanges

-- Not preserved.

Nasal – Large, thick, and massive, bordering the retracted external nares [c. 8(1)]; set in socket in anterior margin of frontal and exposed dorsally. The posterior end of the nasal is slightly recessed below the surface of the frontal roof, causing the nasal-frontal suture to be well mar-

AB	Total length
AG	Anterior tip to front of ascending ramus
AP	Anterior tip to rear of principal mental foramen
AQ	Anterior tip to front of mandibular foramen
AS	Length of symphysis
BG	Posterior extremity to front of ascending ramus
BQ	Posterior extremity to front of mandibular foramen
DF	Distance between anterior and posterior ventral extremities
DK	Height at mandibular notch
DL	Height at condyle
EF	Height at deflection point of horizontal ramus
EU	Deflection point to rear of alveolar row
GH	Minimum anteroposterior breadth of ascending ramus
GP	Front of ascending ramus to rear of principal mental foramen
MN	Top of ventral curvature of horizontal ramus to line connecting ventral extremities
MO	Minimum dorsoventral breadth of horizontal ramus
RR'	Maximum breadth of masticating surface
SQ	Rear of symphysis to front of mandibular foramen
TU	Length of alveolar row
XX'	Minimum width between condyles
MD	Mandibular deflection (degrees)

Dimension	MAFI unnum. [Fazekasboda] (juvenile)	NHMW 1885 [PS3350] [Ottakring] (juvenile)	STMBV Met/0001 [Gainfarn] (old adult) (left)	STMBV Met/0001 [Gainfarn] (old adult) (right)
AB	--	190	260e	--
AG	--	144	--	215e
AP	51	68	--	120e
AQ	--	nm	--	135e
AS	54e	nm	--	75e
BG	62e	65	85e	--
BQ	53e	--	--	--
DF	--	100e	--	130e
DK	--	111e	--	--
DL	--	121e	--	--
EF	--	--	113e +?	--
EU	--	--	127	--
GH	--	54	74	--
GP	--	77	107	107
MN	--	21e	--	32e
MO	--	49	83	81
RR'	30e	--	--	44e
SQ	--	--	--	64e
TU	--	--	67	67e
MD	--	60e	56e	62e

**TABLE 3:** Measurements (in mm) of mandibles of Badenian *Metaxytherium medium* from the Central Paratethys. Measurements designated by letters are modified from Domning (1988) and earlier works. e = estimated; nm = not measured; + = measurement on incomplete element.



ked. Anteriorly, the surface of the nasal is transversely concave for reception of the premaxilla. The nasals are separated in the midline by a nasal incisure and (at the posterior end) by processes of the frontals [c. 31(1), 32(1)]. (In BLLM 32816 the nasals are in contact; see discussion below.) The dorsal width of the nasal cavity between the nasals is ~22 mm.

**Frontal** – The supraorbital processes are broken off at their bases. Orbicular apophyses are absent. A thin lamina orbitalis [c. 38(0)] forms the medial wall of the temporal fossa and the lateral wall of a large hollow, open anteriorly, whose medial wall was formed by the ethmoid. A crista intratemporalis is absent, and the ventral part of the wall of the temporal fossa is not recessed. The internasal processes are broken, but do not seem to have extended very far anteriorly between the nasals (perhaps only 1–2 cm beyond the rear end of the nasal). The frontal border surely lay well posterior to the posterior corner of the supraorbital process (though still at the level of the base of the process); thus the posterior border of the mesorostral fossa may have been incised to some extent [c. 37(1?)]. The same is true of the skull roof from Retznei (see below); and also of skulls of *M. medium* from France (Chazé-Henri specimen MNHN Fs 5001, Moncharmont Zei and Moncharmont, 1987: pl. 3, fig. 1; unpublished skull LPB 16001) and Italy (MPUN M18403, Moncharmont Zei and Moncharmont, 1987), *M. "calvertense"* (= *crataegense*) from Peru (MNHN PRU 7, Muizon and Domning, 1985), a skull fragment of *Metaxytherium* sp. from Libya (BMNH M82421; Heal, 1973), some specimens of *M. floridanum* (Domning, 1988; e.g., USNM 359670, 359748), a cf. *Metaxytherium* from Brazil (Toledo and Domning, 1991), and the holotype of *M. arctodites* (Aranda-Manteca et al., 1994). In short, this condition occurs widely, at least as a polymorphism, in Middle Miocene *Metaxytherium*, though not in earlier or later species of the genus (Domning and Pervesler, 2001; Carone and Domning, 2007; Sorbi et al., 2012). The median portion of the frontal roof is slightly convex [c. 42(0)]. The temporal crests are weakly developed. The anterior end of the fronto-parietal suture lies 3 cm behind the nasal. The intracranial surface formed by the frontals is 3 cm in length in the midline.

**Parietal** – The parietal roof is 24 mm thick in the anterior midline, flat anteroposteriorly, and strongly concave between thick, rounded, lyriform temporal crests separated by ~2 cm (type C of Domning, 1988; in BLLM 32816 they are of type B: upraised on the lateral edges of a markedly concave roof). The posterolateral corners of the roof are indented by the squamosals; the minimum width between these indentations is ~78 mm (74 mm in BLLM 32816). A small bump is present anterior to the external occipital protuberance. The internal occipital protuberance is distinct but blunt; the tentorium forms a straight transverse ridge; and the transverse sulcus is narrow and distinct throughout its length, with distinct but not very deep lateral pits. (In BLLM 32816 the tentorium is indistinct and the sulcus has no pits.) The bony falx cerebri is distinct as far as the fronto-parietal suture, and only slightly rounded at its anterior end. No emissary foramina are evident.

**Supraoccipital** – Pentagonal in outline, with rounded dorsola-

teral corners. Forms angle of ~114° with the posterior parietal roof. The external occipital protuberance rises slightly above the plane of the parietal roof; the median ridge below it is weakly developed. The nuchal crest is strongly convex anterad but indistinct at its lateral end (distinct laterally in BLLM 32816). The area of insertion for the semispinalis capitis muscle is trapezoidal, shallowly concave, and faces more dorsally than posteriorly; it extends halfway to the ventral margin of the supraoccipital, and its ventromedial edge is well defined. The lower part of the supraoccipital is strongly concave medially and convex laterally. Its lateral border is thick and rounded, sloping outward at the bottom, with only a slightly overhanging upper corner. The ratio of width to height of the supraoccipital is 1.53. The sutural surfaces for the exoccipitals do not appear to be separated in the midline, although the exoccipitals themselves are.

**Exoccipital** – Do not meet dorsally in a median suture [c. 66(1)]. The foramen magnum has an acute dorsal peak. The dorso-lateral border of the bone is smoothly rounded [c. 70(0)] and has a flat surface, facing laterad and slightly anterad, which is broadest (18 mm) at the level of the top of the supracondylar fossa. The fossa is moderately deep [c. 67(2)].

**Basioccipital** – As in other dugongids, the basioccipital bears a pair of rugosities (here separated by a deep keel) for the longus capitis muscles. Its posterior slope is steeper than the anterior.

**Basisphenoid** – The sella turcica is shallow; the region of the tuberculum sellae bears an abraded ridge.

**Presphenoid** – No elevated shelf (orbitosphenoidal crest) overhangs the area of the optic chiasm, nor are distinct chiasmatic grooves present.

**Orbitosphenoid** – The optic foramen lies at the level of the dorsal side of the sphenorbital foramen.

**Alisphenoid** – The lateral side of the pterygoid process is smooth, with little sculpture.

**Pterygoid** – The pterygoid fossa is well developed, ~1 cm wide, extending above the level of the roof of the internal nares [c. 102(1)]. Its lateral and medial edges converge dorsally but do not have a well-defined intersection; the lateral edge forms a projecting flange at its top end, whereas the medial edge becomes indistinct. The medial edge of the fossa projects farther posteriorly than the lateral edge.

**Maxilla** – The alveolar portion is heavy and massive; its dorsal edge helped form the wall of the temporal fossa. The edges of the palatal surface were presumably lyriform, but the anterior portion of the bone is fragmented. No part of the intermaxillary suture remains. The zygomatic-orbital bridge is elevated only ~6 mm above the alveolar margin [c. 11(0)]. The bridge is short anteroposteriorly [c. 14(1)], with a thin anterior edge and a thick, rounded posterior edge. The infraorbital foramen is not preserved.

**Squamosal** – Only the left squamosal is preserved (Fig. 6D), except for the posttympanic portion of the right squamosal. Its broad and rounded posterodorsal margin reached the level of the parietal roof [c. 76(1)]. Its posterior margin is slightly not-

ched above the sigmoid ridge, and below that it has a deep mastoid indentation. The sigmoid ridge is prominent [c. 74(0)], and broad in its midsection. The external auditory meatus is ~13 mm long mediolaterally [c. 75(0)], a seemingly atavistic variation from the condition 75(1) that is usual in *Metaxytherium* but resembling one specimen of *M. krahuletzii* (Domning and Pervesler, 2001: 22). The meatus is semicircular in lateral view, about as wide anteroposteriorly as high [c. 82(1)]. The postglenoid process and postarticular fossa are well developed; the temporal condyle has an irregularly oval outline. The processus retroversus is moderately inflected [c. 77(1)], does not project below the line of suture with the jugal, and is turned in ventrally; its posterior end has distinct dorsal and ventral terminations, the dorsal one being a continuation of the zygomatic root. The zygomatic process is broader posteriorly than anteriorly; its posterodorsal edge is convex in outline (concave in BLLM 32816) and also convex laterad. Its medial side is relatively flat [c. 84(1)].

**Jugal** – Only the left jugal is preserved (Fig. 6E). The preorbital process is flattened [c. 88(0)], and presumably did not contact the premaxilla [c. 87(0?)]. The ventralmost point of the bone is missing, but lay approximately below the rear edge of the orbit [c. 85(1?)] (in BLLM 32816 it lies below the posterior half of the orbit). The border behind it is smooth and concave in outline. The ventral margin of the orbit does not overhang the bone's lateral surface [c. 90(0)]. There is a slightly raised postorbital process, behind which the initially broad and concave surface in contact with the squamosal tapers posteriorly. The posterior process lacks its termination, but was longer than the diameter of the orbit [c. 89(0)].

**Periotic** – Not fused with other bones, but set in a socket of the squamosal [c. 115(1)]. The lateral surfaces are smooth; a slight groove partly demarcates the pars temporalis from the pars mastoideus. The anteroventral notch between these two portions is broad and V-shaped. The anteromedial end of the pars temporalis is tapering. The pars mastoideus bears a slightly raised processus fonticulus that fits into the mastoid foramen. The posterolateral edge of the pars mastoideus is relatively sharp. The pars petrosa is broken.

**Mandible** – The left and right dentaries (Table 3; Fig. 7) were found in articulation, compressed together. The condyle and coronoid process are missing from both. The notch in the rear margin below the condyle is smooth in outline, not stepped at its lower end [c. 125(2)]. The medial side of the angle is a flat area 1.5 cm wide, lateral to which the lower end of the internal pterygoid fossa is deeply excavated. In this old adult, the coronoid arch is narrow (9 mm) dorsoventrally; the dental capsule is enclosed within the mandible [c. 127(1)] and is degenerate, indicating maturity; and the m3 alveolus is separated by 28 mm from the rear of the coronoid canal. Lateral to m3, the bone surface slopes steeply downward without formation of a shelf. The horizontal ramus is short though not very deep [c. 128(1)]. Its ventral border is strongly concave [c. 122(3)] in its posterior portion, and apparently not tangent to the angle [c. 129(1?)]; but anteriorly, this curvature diminishes and the

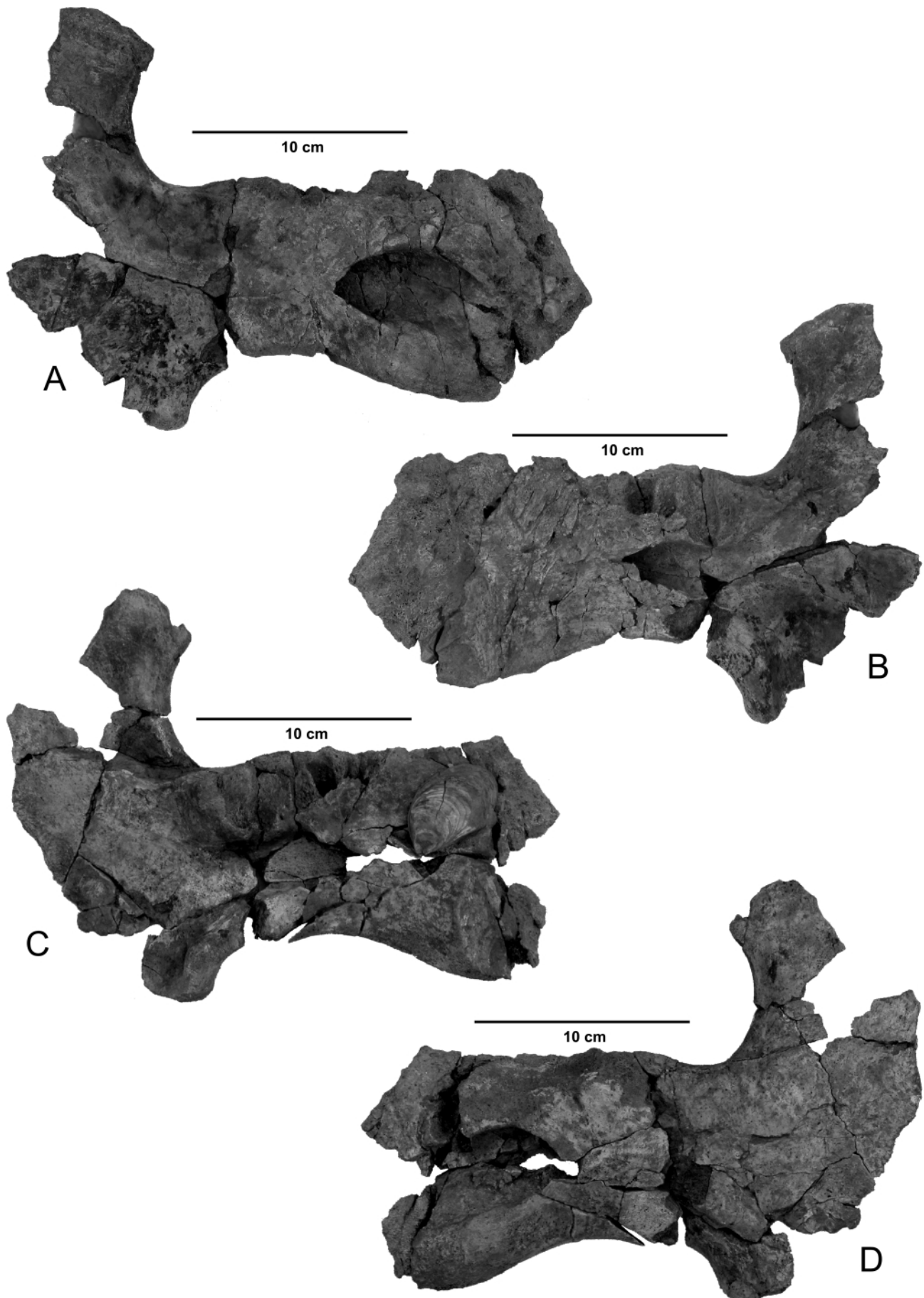
outline of the ramus even appears slightly convex. This, however, may partly be an artifact of abrasion on the ventral side of the symphysis, the amount of which is unclear. The posterior part of the ventral edge is sharper than the anterior part. The dorsal edge of the ramus is thin anterior to the tooth row. The single mental foramen [c. 123(1)] is proportionately larger than in other *Metaxytherium*. It extends back to the level of m1. Its anterodorsal margin is rounded rather than sharp; in this region large nutrient canals pierce the roof of the mandibular canal. Deflection of the masticating surface is abrupt, ~60°. The masticating surface is damaged but was broad [c. 121(1)]; on the right side are visible the remains of two or three circular pits ~1 cm in diameter (vestigial incisor alveoli). The edges of this surface were convex, thin, and overhanging. The symphyseal suture is unfused posteroventrally and displays weak vertical interdigitations, but is apparently ankylosed anteriorly and dorsally.

**Dentition** – Owing to loss of the premaxillae, nothing can be said about presence or morphology of an I1 tusk. As is normal for an old adult *Metaxytherium*, the cheek dentition is reduced to M1-3/m1-3 [c. 150(0), 151(0), 157(2), 158(0)]. Even

Tooth and Dimension	MAFI unnum. [Fazekasboda] (juvenile) (left uppers, right lowers)	BLLM 32816 (juvenile) (left)	MAFI V.10973 (subadult) (left)
DP4 L	17.8	15.3w	--
DP4 AW	14	13.7	--
DP4 PW	14.6	13	--
DP5 L	20	17e	--
DP5 AW	18.5	18.4	--
DP5 PW	17.8	15.8	--
M1 L	21.5	20e	--
M1 AW	24.2	21.8	--
M1 PW	17.1	18.2	--
M2 L	--	25e	--
M2 AW	--	22	--
M2 PW	--	nm	--
M3 L	--	--	--
M3 AW	--	--	--
M3 PW	--	--	--
dp4 L	18.6	--	9
dp4 AW	11.9	--	--
dp4 PW	13.2	--	--
dp5 L	18e	--	14
dp5 AW	16.5e	--	--
dp5 PW	16.3e	--	--
m1 L	24.4	--	20
m1 AW	16+	--	--
m1 PW	17.4	--	--
m2 L	--	--	31.8
m2 AW	--	--	24.7
m2 PW	--	--	22.9
m3 L	--	--	32.3
m3 AW	--	--	--
m3 PW	--	--	23.9

**TABLE 4:** Linear dimensions (in mm) of associated cheek dentitions of Badenian *Metaxytherium medium* and *Haplosiren leganyii* (holotype: MAFI V.10973) from the Central Paratethys. L = crown length; AW = anterior width; PW = posterior width; e = estimated; nm = not measured; w = dimension reduced by wear; + = measurement on damaged tooth. Measurements in parentheses refer to empty alveoli.

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe



**FIGURE 7:** *Metaxytherium medium*, Gainfarn specimen (STMBV/Met/0001). A: Right mandible, lateral view (Fig. 3, #37). B: Right mandible, medial view (Fig. 3, #37). C: Left mandible, medial view (Fig. 3, #37). D: Left mandible, lateral view (Fig. 3, #37).



the left and right m1 were probably lost before death, as their alveoli are already reduced in size and were probably being resorbed. As noted above, the m3 alveolus is separated by 28 mm from the rear of the coronoid canal, also a sign of advanced age.

One very heavily worn upper tooth, probably the right M1, is preserved; its width is reduced by wear to 23.5 mm, and its crown length is reduced by interdental wear even more, to only 19.1 mm. Fragments of another tooth, possibly m2, are present; but the only tooth relatively well preserved is the left m3 (Table 5; Fig. 6C). The posterior root is large and triangular in cross section, in contrast to the more anteroposteriorly flattened anterior root. The occlusal surface is moderately to heavily worn; interdental wear has also removed a significant portion of the mesial surface. Three lophids were present; the large protolophid and the smaller hypolophid are reduced to lakes of dentine, connected at the midline of the crown. The large hypoconulid has only a labial lobe and a posterior central lobe still distinct; these are coalesced with the hypolophid, but probably constituted an originally Y-shaped form (cf. Domning, 1988: 412) as in many other *Metaxytherium*.

**Vertebrae, Ribs** – Show no apparent differences from *M. krahuletzii*.

**Sternum** – Of the three separate elements observed in young *Metaxytherium krahuletzii* (and all fused in older ones), the anterior two are here fused, with the xiphisternum remaining separate (Table 6; Fig. 8A). The manubrium + central element are slightly asymmetrical, and concave dorsally. The manubrium lacks its anterior tip; the spatulate anterior process is not expanded, but is comparable in breadth to the body of the sternum. On the ventral side the manubrium has a low keel. The anterior pair of rib attachments are prominent; the second pair are asymmetrically placed, being located more anteriorly on the left side. The third and last pair are again symmetrical and coincided with the joint between the central element and xiphisternum. Behind this, the xiphisternum narrows slightly, then broadens markedly, thins, and bifurcates, with a narrow median notch separating the left and right cartilage attachments along the nearly straight posterior margin. The xiphisternum is more convex on the presumed ventral side. On the whole, this sternum does not differ significantly from that of *M. krahuletzii*.

**Scapula** (Table 7) – The supraspinous fossa is broad, and its anterior edge is turned somewhat laterally. The spine is high and overhangs posteriorly, without a tuber spinae. The acromion is not preserved. The coracoid process is broken but was inflected medially. The glenoid fossa is deep and elliptical. The

	Tooth	L	AW	PW
NHMW 2007z0106/0001 [Rauchstallbrunngraben]	Left DP5?	16.5	17.9	16.7
NHMW 2012/0156/0001 [Theben-Neudorf]	Left M2	25.9w	25.3	22.0e
IPUW unnum. [Müllendorf]	Right M2?	20.3	23.1	20
IPUW unnum. [Müllendorf]	Left m2?	22.2	--	18.8
IPUW unnum. [Neudorf/March]	Left m2?	21.4	18	17.3
NHMW 1859.I.13 [PS3363] [Garschöntal] (Abel, 1904: 110)	Left m2?	23.5	--	18.6+
NHMW 1850.XVI.21 [PS3360] [Neudorf] (Peters, 1867: pl. 7, fig. 2; Abel, 1904: pl. 1, fig. 18))	Left m2	23.3	19.5e	19.0e
NHMW 1997z0178/1983 [Neudorf]	Left m2	21.7	17.7	18.2
NHMW [PS3358] [?Wöllersdorf-Fischau] (Abel, 1904: pl. 1, fig. 17)	Left m3	29.8	21.7	20
NHMW 1850.XXVI.20 [PS3361] [Mannersdorf] (Peters, 1867: pl. 7, fig. 3; Abel, 1904: pl. 1, fig. 19)	Right m3?	26.1	18.9	19.2
NHMW 1865.I.1181 [PS3362] [Neudorf] (Peters, 1867: pl. 7, fig. 1)	Right m3	31.3w	24.3	22.6
NHMW 1952/37 [Müllendorf]	Left m3	32	20.9	20.4
STMBV Met/0001 [Gainfarn]	Left m3	30.0w	24.7	21.4
MAFI Ob-3040 [Marz (Márczfalva–Péherko-bánya)]	Right m3	27.8w	21.6w	18.1w

**TABLE 5:** Linear dimensions (in mm) of isolated cheek teeth of Badenian *Metaxytherium medium* from the Central Paratethys. L = crown length; AW = anterior width; PW = posterior width; e = estimated; w = dimension reduced by wear; + = measurement on damaged tooth.

posterodorsal corner of the blade is missing; but on the fragmentary scapula (IPUW 1007) collected at Gainfarn in 2000 (which is comparable in size to that of the 2006 specimen), the teres major origin is 89 mm long, with a prominent teres protuberance.

**Humerus** (Table 8; Fig. 8B,C,D) – Robust and dumbbell-shaped, with large tubercles, deep bicipital groove, and a nearly circular head. The curvature of the head is much flatter both

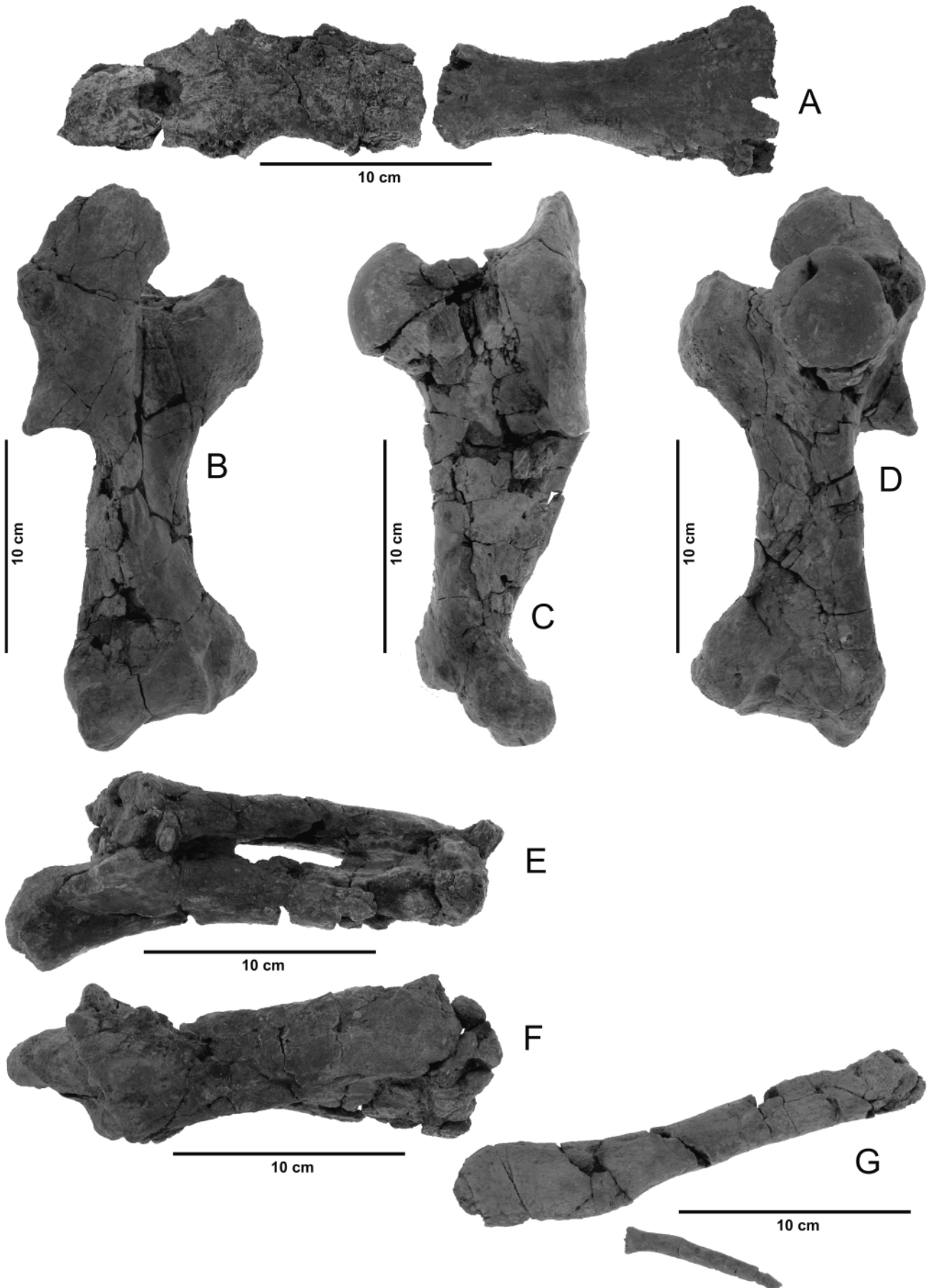
Dimension	NHMW 1885 [PS 3367] [Ottakring]	STMBV Met/0001 [Gainfarn]
Total length	285+	310+
<b>MANUBRIUM</b>		
Length	nm*	nm**
Breadth at anterior rib articulations	69	64
Breadth of anterior process near middle of its length	nm	42
Length of anterior process in midline	70e	64+
Posterior thickness	15	nm*
Breadth of anterior end	73	41+
Maximum thickness at keel	18	25
<b>CENTRAL ELEMENT</b>		
Length	nm*	nm**
Posterior thickness	nm*	25
<b>XIPHISTERNUM</b>		
Length	115+	153
Anterior breadth	nm*	49
Minimum breadth	38e	33
Maximum breadth posteriorly	--	90e
Anterior thickness	nm	26
Posterior thickness	10e	7

\* Elements of sternum fused; boundaries not distinguishable.

\*\* Combined length of manubrium and central element = 60+ mm.

**TABLE 6:** Measurements (mm) of sterna of *Metaxytherium medium* from the Central Paratethys; e = estimated; nm = not measured; + = measurement on damaged bone.

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe



**FIGURE 8:** *Metaxytherium medium*, Gainfarn specimen (STMBV/Met/0001). A: Sternum, anterior end at left, ventral view (xiphisternum: Fig. 4, #64). B: Right humerus, anterior view (Fig. 4, #13). C: Right humerus, lateral view (Fig. 4, #13). D: Right humerus, posterior view (Fig. 4, #13). E: Right radius-ulna, lateral view (Fig. 4, #15). F: Right radius-ulna, anterior view (Fig. 4, #15). G: Right innominate with ?femur, lateral views (Fig. 4, #10, #11).

longitudinally and mediolaterally than in *M. krahuletzii*, in part because the proximal margin of the articular surface does not extend as far anteriorly. The greater tubercle extends well proximad of the head, has a large anteromedial flange, and bears distinct supraspinatus and infraspinatus muscle scars. The lesser tubercle is perhaps slightly more elongated distally than in *M. krahuletzii*. There is a weak triangular protuberance on the lateral side of the neck. The tubercles diverge at an angle of  $\sim 80^\circ$  as seen in proximal view. The deltoid crest is prominent and recurved, and is continued by the deltopectoral crest, which is slightly roughened at its distal end for insertion of m. pectoralis major. Posterior and distal to this insertion on the medial side is a longitudinal pit  $\sim 2$  cm long, probably for another muscle insertion. The shaft is relatively thick, corresponding to the stockier morph of Middle Miocene *Metaxytherium* (cf. Domning and Pervesler, 2001: 36). The trochlea is canted obliquely to the shaft at an angle of  $\sim 75^\circ$ - $80^\circ$ . The trochlear articular surface has a barely discernible notch in its posterolateral side for a humero-ular ligament. The olecranon fossa is well defined. The coronoid fossa has a large lateral pit, and a medial pit that is much larger on the right humerus than on the left.

**Radius-ulna (Table 9; Fig. 8E,F)**—Fused to each other with pronounced torsion. The anterior side of the olecranon process is tilted back at a sharp angle ( $60^\circ$ - $70^\circ$ ) to the ulnar shaft. The semilunar articular surface is notched on its medial side; on the lateral side at the same level, there may also be a notch in the articular surface, and lateral to it there is a pronounced shoulder on the ulna. The Gainfarn specimen is chiefly remarkable for the proportionately great mediolateral breadth of the humero-radial articular surface, its steep inclination (deviating some  $25^\circ$ - $30^\circ$  from perpendicular to the long axis of the ulna), and the overhanging lip at the lateral edge of the surface. This lip gives the appearance of arthritic pathology, but the left and right bones are nearly symmetrical and the humeri show no corresponding pathology. The pit on the medial side of the radioulnar junction for the biceps tendon is very large and deep. As is typical in *Metaxytherium*, the shaft of the radius is compressed anteroposteriorly, while

that of the ulna is more nearly triangular in cross section. In the Gainfarn specimen, the posterior border of the ulna is low and rounded for most of its length rather than sharp. The distal end, though present on the right side, is badly damaged; more informative are the separated distal epiphysis of the right radius (holotype of *M. petersi*, Hainburg) and the complete distal radius-ulna from Kalksburg (Abel, 1904: 121-122). The former differs from the latter in that the entire anteromedial half of its articular surface is strongly and evenly convex, rather than just the portion within 1 cm of the anteromedial margin; also, in that the posterolateral edge of the articular surface, adjacent to the ulna, is distinctly raised. Furthermore, in the Hainburg specimen there is a narrow, shallow nonarticular area (possibly for attachment of a ligament) extending onto the articular surface for a distance of  $\sim 1$  cm posterolaterally.

Dimension	IPUW 1007 ["Gainfarn 2000"] (left)	STMBV Met/0001 [Gainfarn] (left)	STMBV Met/0001 [Gainfarn] (right)
Maximum length, vertebral border to border of glenoid fossa (AB)	--	--	310e
Mediolateral width of glenoid fossa (BI)	--	51e	--
Lateral border of glenoid fossa to inside of concave distal end of spine (BJ)	--	53e	--
Maximum breadth of blade dorsally (CD)	--	--	--
Minimum anteroposterior breadth of neck (EF)	--	--	--
Maximum anteroposterior breadth of distal end (GH)	--	--	--
Summit of spine to medial side of blade, measured parallel to plane tangent to posterior edges of spine and neck (KL)	--	--	60
Anteroposterior length of glenoid fossa (MN)	--	60e	--
Length of teres major origin from teres protuberance to posterior corner of blade (TMO)	89	--	--

**TABLE 7:** Measurements (mm) of scapulae of *Metaxytherium medium* from the Central Paratethys; e = estimated.

	Marz (Márczfalva–Péherkő-bánya)		IPUW unnum.	STMBV Met/0001	STMBV Met/0001
	MAFI Ob-3036 (left)	MAFI Ob-3995/6 (right)	[PS 3342] [Kalksburg] (left)	[Gainfarn] (left)	[Gainfarn] (right)
Maximum length, greater tubercle to distal end (AB)	232	--	248	255	263
Maximum breadth, greater to lesser tubercle (CD)	110e	--	106	113	116
Maximum breadth, ectepicondyle to entepicondyle (EF)	88	--	86	94	99
Maximum thickness, posterior side of head to anterior side of greater tubercle (GH)	99	99	98	108	111
Maximum thickness, posterior to anterior ends of medial rim of trochlea (IJ)	29	31	33	34	38
Maximum (proximolateral-mediolateral) breadth of head (KL)	54+	55	46e	58	57
Minimum (proximomedial-distolateral) breadth of head (MN)	63	63	56e	55	56
Breadth of anterior side of trochlea (OP)	58	56	60	60	64
Length, saddle between head and greater tubercle to saddle of trochlea (QR)	195	--	218	208	210
Maximum mediolateral diameter perpendicular to lateral surface, midshaft (MLD)	49e	--	42e	43	43

**TABLE 8:** Measurements (mm) of humeri of *Metaxytherium medium* from the Central Paratethys; e = estimated; + = measurement on damaged bone.



rally from the anterior extremity.

**Innominate** (Table 10, Fig. 8G) – The proximal (iliac) end is not noticeably inflected, but it bears on its dorsomedial side a broad, slightly roughened concavity extending 5 cm along the shaft. The shaft is straight with an oval cross section. The acetabulum is very shallow, and its rim is incomplete posterovertrally. The ventral and posterior edges of the bone are damaged, so the size of the pubis (if any) and the distal ischial margin cannot be judged. This damage admittedly biases the assessment of gender towards the female; but despite the advanced osteological maturity of this individual, nothing about the pelvis gives the impression of male morphology. In particular, where a portion of the ventral margin of the ischium is preserved (~4 cm behind the acetabulum), the bone was no more than 4 cm wide dorsoventrally – a degree of ischial expansion too slight to suggest a male (cf. *M. krahuletzki*, Domning and Pervesler, 2001: pls. 19-20). In the holotype of *M. petersi* (Abel, 1904: pl. 7, fig. 2), the acetabulum is much deeper and more distinct than in the Gainfarn specimen, and the pubis is distinct; but such differences are within the range of intraspecific variation.

?**Femur** – A slender bone found near the right innominate is

apparently the right femur (Fig. 8G). Its proximal end is flat, subtriangular or trapezoidal, 11 x 13 mm, and rugose, having evidently had a proximal epiphysis. The nearly straight, subcylindrical shaft is 10 mm in diameter; it tapers distally to 7 mm diameter, and apart from a slight bend 2 cm from the proximal end it has no distinct muscle attachments. There is no expansion at the distal end, which was probably blunt though is now damaged. At the distal end the bone has a cancellous core but a denser cortex. Its total length is 73 mm.

## 6. DESCRIPTIONS OF OTHER NEWLY REFERRED SPECIMENS

The following descriptions emphasize features that differ from most other *Metaxytherium*.

### 6.1 RAUCHSTALLBRUNNENGRABEN SKULL

This juvenile skull (NHMW 2007z0106/0001; Tables 2, 5; Fig. 9), mentioned in a field trip guide by Piller et al. (1996: 16), is incompletely prepared and lacks the right premaxilla, occipital bones, and zygomatic arches. A natural endocranial cast is present, together with the left tympanic, periotic, and auditory ossicles.

**Premaxilla** – Anterior surface convex, without a distinct keel. There is no sign of tusk alveoli, though the premaxillary canal is visible close to the anterior end, which is damaged at the tip. The posterior end of the symphysis forms an upraised boss [c. 10(1)]. The rostral deflection was greater than 50°.

**Nasal, Ethmoid, Vomer, Lacrimal** – Not discernible or not preserved.

**Frontal** – Lateral side of supraorbital process long anteroposteriorly (~38 mm); the process is a maximum of 23 mm thick dorsoventrally on its medial side, with a thin (~7 mm) posterolateral corner [c. 36(1)]. Orbicular apophyses are absent. A nasal incisure is absent [c. 37(0)]. The median portion of the roof is slightly convex, with no distinct boss [c. 42(0)]. No crista intratemporalis is present, and the lower part of the temporal surface is not recessed.

**Parietal** – The temporal crests are of type C (Domning, 1988): smoothly rounded, separated by a concavity ~2 cm wide.

**Basisphenoid** – Sutural surface for basioccipital ~25 mm wide.

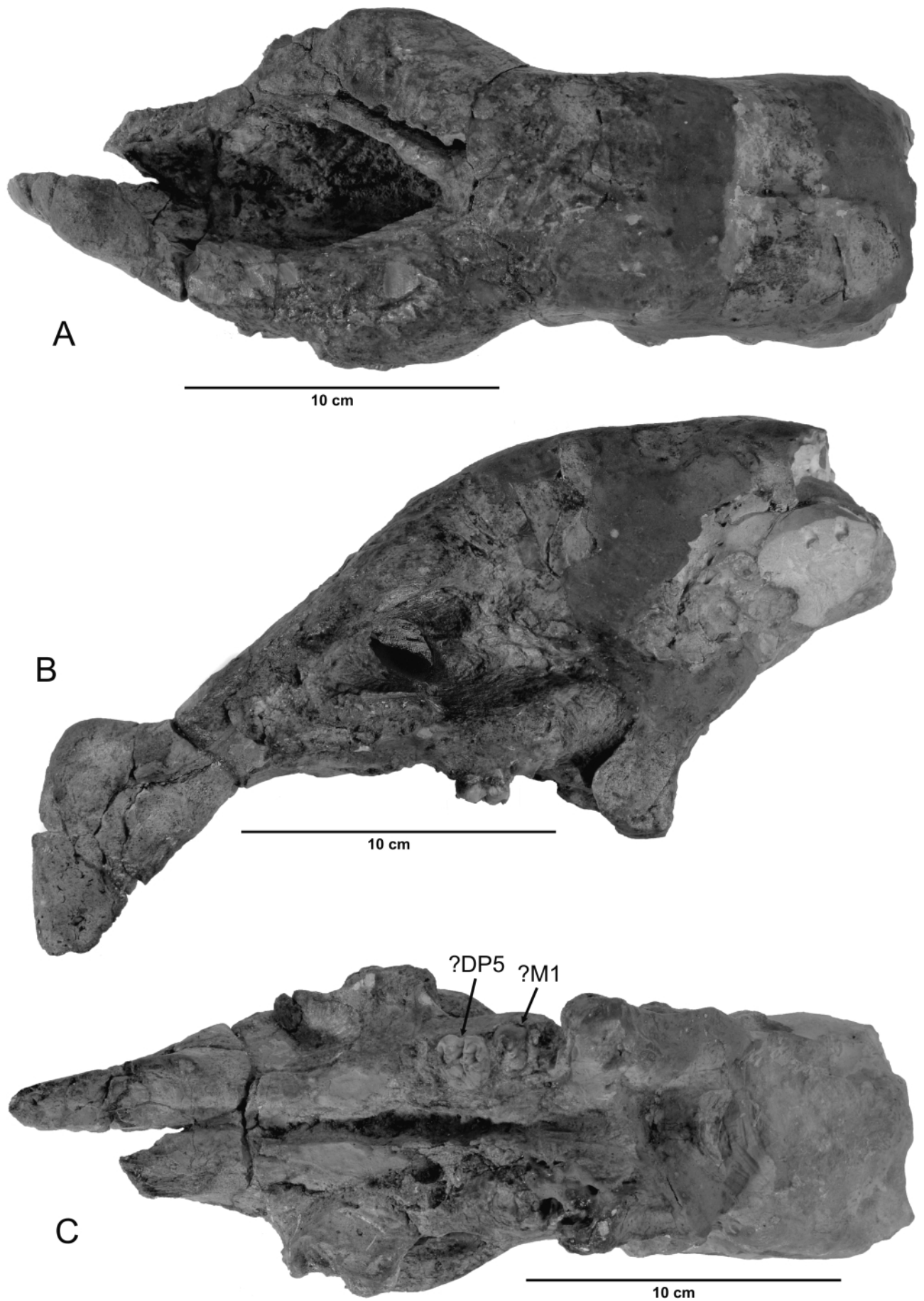
**Alisphenoid** – The lateral surface of the pterygoid process is smooth; length of process ~40 mm. The con-

Dimension	MAFI Ob-3037 [Marz] (right)	STMBV Met/0001 [Gainfarn] (left)	STMBV Met/0001 [Gainfarn] (right)
Total length of ulna (AB)	--	--	205e
Total length of radius, anterior lip of semilunar notch to distal end (CD)	--	--	180e
Height of semilunar notch, anterior tip of olecranon to anterior radial lip of notch (EC)	43	39	38e
Thickness of olecranon, anterior tip to posterior side (EF)	--	47	45e
Distal thickness, anterior side of radius to posterior side of ulna (GH)	--	--	74e
Maximum mediolateral breadth, radial portion of semilunar notch (IJ)	60	70	74e
Maximum mediolateral breadth, ulnar portion of semilunar notch (KL)	30	33e	32e
Minimum mediolateral breadth of semilunar notch at its midsection (MN)	28	36	32e
Minimum thickness of olecranon, posterior side to semilunar notch (OP)	31	37	37

TABLE 9: Measurements (mm) of radii and ulnae of *Metaxytherium medium* from the Central Paratethys; e = estimated.

Dimension	GBAW Inv. Nr. 2006/18/1, #2350 [Hainburg] (left)	STMBV Met/0001 [Gainfarn] (right; old female?)
Total length	200+	218+
Dorsoventral breadth, proximal end	33	29
Mediolateral thickness, proximal end	16	21
Minimum dorsoventral thickness of ilium	22	25
Minimum mediolateral thickness of ilium	15	18
Proximal end of ilium to acetabular area	141	150
Mediolateral thickness at acetabular area	23	23
Anteroposterior diameter of acetabulum	nm	17
Dorsoventral breadth at pubis	45	34+
Maximum dorsoventral breadth of ischium	46+	36+
Mediolateral thickness of distal end	--	15+

TABLE 10: Measurements (mm) of innominates of *Metaxytherium medium* from the Central Paratethys; e = estimated; nm = not measured; + = measurement on damaged bone.



**FIGURE 9:** *Metaxytherium medium*, Rauchstallbrunngraben specimen (NHMW 2007z0106/0001), juvenile skull with left ?DP5 and unerupted ?M1. A: dorsal view. B: left lateral view. C: ventral view.

vexity anterior to the zygomatic root is almost negligible.

**Pterygoid** – The pterygoid fossa is well developed. The posterior width across the tops of the pterygoid processes is ~70 mm (~64 mm in BLLM 32816).

**Palatine** – The extent of the palatines and palatal incisure is unclear [c. 97(?), 99(?)].

**Maxilla** – The palatal gutter is deep. The palatal and rostral surfaces meet in a smooth but abrupt curve. The zygomatic-orbital bridge is elevated ~9 mm above the alveolar margin [c. 11(0)] and has a thick, rounded posterior edge.

**Dentition** – Alveoli are present for a 3-rooted ?DP4. The almost unworn left ?DP5 is preserved (L = 16.5 mm, AW = 17.9 mm, PW = 16.7 mm). An unerupted tooth (M1?) is preserved on each side. The cusp patterns resemble those of BLLM 32816 described by Sickenberg (1928).

## 6.2 ?ST. MARGARETHEN BRAINCASE

This adult specimen (BLLM 32815; Table 2; Fig. 10) displays erosion resembling sandblasting (cf. Thenius, 1952: 109-111) on its supraorbital, pterygoid, and zygomatic processes. The entire rostral and palatal portions, jugals, and ear bones are missing.

**Ethmoid** – The perpendicular plate is 15 mm thick. Several conchae are visible in cross section, but are not fully prepared.

**Nasal** – The nasals are large, set in sockets in the anterior margins of the frontals, and separated in the midline by ~32 mm [c. 31(1), 32(1)]. The right nasal is missing.

**Frontal** – Orbicular apophyses are absent. No nasal incisure extends abaft the nasals [c. 37(0)]. The frontal roof is flat with a median groove [c. 42(0)], not overhanging laterally. The anterior end of the frontoparietal suture lies ~4.5 cm abaft the nasals. Endocranially, the length of the frontals exposed in the midline between the mesethmoid and the parietals is approximately 22 mm, slightly more than in BLLM 32816.

**Parietal** – Maximum width = 84 mm; minimum width of roof at squamosal sutures = 72 mm; thickness in anterior midline ~20 mm. The temporal crests are of type A (Domning, 1988): low, at edges of a nearly flat roof; cranial vault nearly rectangular. No emissary foramen is present. Endocranially, the bony falx cerebri is low and rounded at the frontoparietal suture. The pits at the lateral ends of the transverse sulcus are not very deep.

**Supraoccipital** – Forms an angle of 107° with the after part of the parietals. The dorsal portions of the lateral borders do not overhang, in contrast to BLLM 32816 which here displays (as an individual peculiarity?) a state more primitive than is seen in other *Metaxytherium*. The external occipital protuberance does not rise above the plane of the parietal roof; below it is a distinct median ridge. The exoccipital sutures meet at an angle of ~135° and are separated in the midline by a slight notch. The semispinalis insertions extend less than halfway to the ventral border. The nuchal ridge is indistinct near the squamosal sutures.

**Exoccipital** – The exoccipitals do not meet in the dorsal midline [c. 66(1)]. The dorsolateral border is 18 mm thick, smoothly

rounded, and not overhanging posteriorly. The supracondylar fossa is moderately deep. The hypoglossal (= condyloid) foramen is single. The paroccipital processes extend ~2 mm lower than the condyles. Arc of condylar articular surface ~116°.

**Basioccipital** – Fused with basisphenoid, indicating adulthood. Width at suture = 40 mm.

**Basisphenoid** – The sella turcica is shallow; the region of the tuberculum sellae is rugose.

**Presphenoid** – No elevated shelf overhangs chiasmatic grooves.

**Orbitosphenoid** – The optic foramen lies at the level of the dorsal side of the sphenorbital fissure.

**Alisphenoid** – The lateral surface of the pterygoid process is smooth where preserved. No convexity is present anterior to the zygomatic root.

**Pterygoid** – The pterygoid fossa is mostly obliterated by erosion. Posterior width across tops of pterygoid processes = 69 mm.

**Squamosal** – Dorsally in contact with the squared posterior part of the parietal roof [c. 76(1)], but does not have a narrow posterodorsal process as in some *Metaxytherium krahuletzii* or *Halitherium christolii* (cf. Domning and Pervesler, 2001: 22). The sigmoid ridge is prominent, its dorsal shoulder strongly bent. The external auditory meatus is 14 mm long mediolaterally, as is the case aberrantly in some *M. krahuletzii* (Domning and Pervesler, 2001: 22) [c. 75(0) rather than (1) as would be expected]. The surface of the cranial portion dorsal to the zygomatic root is not inflated. The processus retroversus is distinctly double, protruding below the zygomatic root, but not turned in ventrally to a noticeable degree; medial to it, the bone is deeply concave. The posterodorsal edge of the zygomatic process is slightly concave in outline, and very slightly convex laterad.

## 6.3 MÜLLENDORF SKELETON

This juvenile specimen comprises the skull roof, squamosals, right petiotic, right scapula fragment, several unfused neural arches of vertebrae, and numerous ribs. Cranial measurements are included in Table 2.

**Parietal** – The temporal crests are of type A, but weakly developed. The minimum width of the roof at the squamosal sutures is 59 mm. There is no emissary foramen or median bump on the posterior part of the roof.

## 6.4 RETZNEI SKULL ROOF

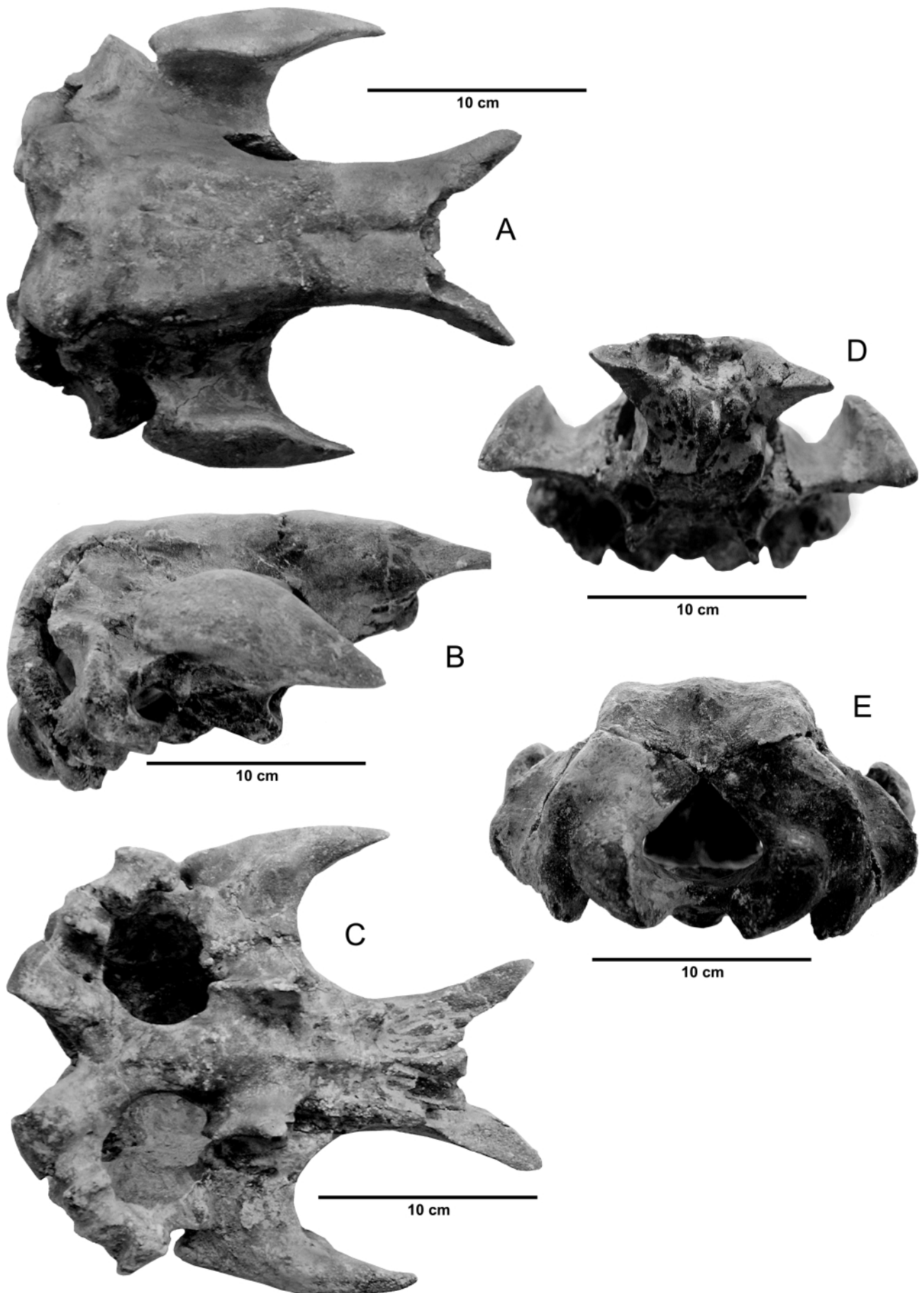
This adult specimen comprises the frontals, parietals, supraoccipital, and a natural endocranial cast (Table 2; Fig. 6B).

**Nasal** – The nasals were probably separated in the midline [c. 31(1), 32(1)].

**Frontal** – A small orbicular apophysis is present on the right side. The anterior end of the frontoparietal suture lies ~4 cm abaft the nasals. The midline length of the endocranial surface is ~32 mm.

**Parietal** – The parietal roof is convex anteroposteriorly, and 21 mm thick in the anterior midline; the temporal crests are of type B. The minimum width of the roof at the squamosal sutures is 69 mm. There is a low median bump on the posterior





**FIGURE 10:** *Metaxytherium medium*, ?St. Margarethen specimen (BLLM 32815), adult braincase. A: dorsal view. B: right lateral view. C: ventral view. D: anterior view. E: posterior view.

part of the roof. Behind it, a very large emissary foramen ~5 mm in diameter extends from the top of the external occipital protuberance to the transverse sulcus. The dorsoventral thickness of the bone at the sulcus is 33 mm. Endocranially, no pits are present at the ends of the sulcus, and the bony falx cerebri is flat at the frontoparietal suture.

**Supraoccipital** – The median crest is very strong. No notch separates the exoccipital sutures.

### 6.5 FAZEKASBODA SKELETON

This juvenile specimen in the MAFI collection includes the parietal-supraoccipital skullcap, right squamosal, ear bones, partial mandible, left DP4-M1 and right dp4-m1, in addition to vertebrae and ribs (Tables 2-4).

**Parietal** – Maximum width = 86 mm; minimum width of roof at squamosal sutures = 76 mm; thickness in anterior midline = 12 mm. The temporal crests may be of type C but have very little relief. Endocranially, the internal occipital protuberance, tentorium, and transverse sulcus are very weak; the bony falx cerebri is relatively sharp at the frontoparietal suture. The dorsoventral thickness at the transverse sulcus is 22 mm. Emissary foramina are absent. A low median bump is present on the posterior part of the roof.

**Supraoccipital** – Forms an angle of 127° with the after part of the parietals. The nuchal ridge distinctly extends to the squamosal sutures. The external occipital protuberance does not rise above the plane of the parietal roof; below it is a distinct median ridge. The semispinalis insertions are only faintly marked. The exoccipital sutures are separated in the midline, possibly by a notch.

**Squamosal** – The surface dorsal to the zygomatic root is not inflated. A prominent foramen or canal deeply notches the dorsal edge of the cranial portion. The zygomatic process is much broader posteriorly than anteriorly, thick and massive, and sigmoid in lateral view (as is typical for juveniles; cf. *Dusisiren jordani*, Domning, 1978: pl. 4, figs. a,b). The postero-dorsal edge is concave in outline, and convex laterad. The processus retroversus is distinctly double, and turned ventrally. The medial and lateral edges of the anterior tip are about equally blunt.

**Mandible** – The anteroventral outline of the symphysis is convex anteroposteriorly.

**Dentition** – The fourth deciduous premolars are erupted; DP4 is unworn, dp4 slightly worn. DP5 and dp5 are beginning to erupt, and are unworn. M1 and m1 are unerupted. The enamel is not wrinkled. DP4 probably has three roots like DP5. The cusp patterns resemble those of other *Metaxytherium*. M1 has a lingual cleft between the precingulum and protocone. The semimolariform dp4 has three lophids; the anterior one is joined to the protolophid by a spur labial to the midline; the transverse valley is open; the hypolophid is joined to the middle cusplule of the postcingulum by a spur lingual to the midline. Of the three postcingular cusplules, the middle is largest and the lingual smallest. On dp5, the hypoconulid lophule lacks distinct cusplules or a median ridge forming a Y-shape

(cf. Domning, 1988: 412). On m1, the “Y” is fairly distinct, but the “G” shape of the protolophid is indistinct.

**Rib 1 (left)** – A process for m. longus capitis is present on the underside of the neck. Total length = 120 mm; tip of capitulum to lateral edge of tuberculum = 37 mm; mid-shaft diameters = 23 x 16 mm.

### 7. COMPARISONS AND RECONSIDERATIONS OF PHYLETIC RELATIONSHIPS

The Miocene and Pliocene *Metaxytherium* of Europe and North Africa form a single lineage of four chronospecies (Domning and Thomas, 1987; Sorbi et al., 2012): *M. krahuletzki* (Burdigalian; Eggenburgian-Ottnangian), *M. medium* (Langhian-Tortonian), *M. serresii* (latest Tortonian-Zanclean), and *M. subapenninum* (Zanclean-Piacenzian) (Pilleri, 1988; Domning and Pervesler 2001; Carone and Domning, 2007; Bianucci et al., 2008; Sorbi et al., 2012). All these species are assumed to have lived throughout the contiguous, shallow marine waters of the Mediterranean-Paratethyan realm. However, except for *M. krahuletzki*, which is best known from Austria, this lineage is best documented from western Europe, Mediterranean islands, and North Africa, especially France, Spain, Italy, and Libya. Moreover, apart from the Early Miocene (Aquitanean-Burdigalian) dugongine *Rytiodus* (Domning and Sorbi, 2011) and the miosirenines *Miosiren* (Burdigalian) and *Prohalicore* (Serravallian) (Sorbi, 2008a), no other Neogene sirenians are definitely known to have inhabited the Mediterranean-Paratethyan region.

The fossil record of Central Europe, therefore, presents an apparent anomaly in that the sirenians of this area, as hitherto interpreted, do not fit the simple pattern of a single, anagenetically-evolving halitheriine lineage: one or more additional species or genera reportedly occur in the Middle Miocene (Badenian) of the Vienna Basin and neighboring areas, and the expected species *Metaxytherium medium* has hitherto not even been recognized there. Instead, workers as far back as Abel (1904) described the Vienna Basin sirenians as a separate species (*M. petersi*), later given its own genus *Thalattosiren* by Sickenberg (1928). Subsequently, Kretzoi (1951) named yet another new genus and species (*Haplosiren leganyii*) from “Tortonian” deposits in Hungary (this presumably reflects not the western European but the older, Paratethyan sense of the term “Tortonian”, which is approximately equivalent to the Badenian in present usage).

These Paratethyan depositional basins were connected to each other and to the Mediterranean from the Early Miocene up through the middle Badenian, though by the late Badenian the Mediterranean connection had been lost and a marine connection with the Eastern Paratethys and Indopacific (interrupted in the Ottnangian-Karpatian and middle Badenian) had been re-established (Rögl and Steininger, 1983; Rögl, 1998, 1999, Meulenkamp and Sissingh, 2003; Bianucci et al. 2011).

Thus it is possible that distinct taxa of sirenians (Indopacific immigrants, and/or endemics that evolved in the Paratethys in isolation from Mediterranean forms) might have appeared there

during or after the late Badenian, but evolution of Paratethyan endemics is unlikely to have occurred earlier. So how are the reportedly distinct taxa to be understood?

### 7.1 DISTRIBUTION OF “*METAXYTHERIUM PETERSI*”

Material from other parts of Europe, and even America, has occasionally been referred to *M. petersi* or *Thalattosiren*, but these referrals are not convincing:

- A humerus from the Middle Miocene of Portugal was described by Zbyszewski (1944) as an *M. petersi* resembling in its dimensions the specimen from Kalksburg – particularly in the 80° angle of divergence of the tubercles. However, this aspect of the specimen was not illustrated, and it is not clear how the measurement was made. The shaft of the bone is extremely long and parallel-sided, more so even than in *M. krahuletzki*, in which the divergence of the tubercles can be as great as 85°. Therefore, the taxonomic assignment of the Portuguese humerus remains uncertain.
- Depéret and Roman (1920: 29-30, pl. 7, fig. 4) referred to “*M. aff. petersi*” a braincase from the “Vindobonian molasse” of Mont-de-Marsan, Landes, France, primarily on the basis of the form and degree of separation of its temporal crests (apparently of type A) in contrast to those of *M. medium* from the Loire Basin. However, although the latter sample has a notably high incidence of closely-spaced crests (type E) (Domning, 1988: 418), the form of the temporal crests is notoriously variable in *Metaxytherium*, and some other French *M. medium* also exhibit crests of types A, B, or C. Therefore this referral cannot be considered well founded.
- Sirenian remains from the Badenian limestones near Pińczów, southern Poland, have also been cited as *Thalattosiren* sp. (Czyżewska and Radwański, 1991; Wolsan, 1991), but without any morphological justification being offered. This name may have been used simply because the Vienna Basin sirenians were closer geographically and stratigraphically (and hence presumably taxonomically) to the Polish ones than any others.
- Similarly, Šuklje (1938) reported sirenian remains from “Mediterranean sandstone” near Zagreb and Samobor, Croatia, said to be “most probably identical” with *M. petersi* from the Vienna Basin. These included isolated teeth, a radius, vertebrae, and ribs. Although a partial molar was illustrated, it does not suffice for a specific identification.
- Pilleri (1987: 31-33) identified a Burdigalian humerus from Othmarsingen, Switzerland, as *M. cf. petersi*, based on its resemblance to one referred to that species by Abel (1904). However, no particular traits were adduced that support this species assignment to the exclusion of the more chronostratigraphically probable *M. krahuletzki*.
- VanderHoof (1941) identified a Middle Miocene skull and skeleton from Santa Cruz, California, as *M. petersi*. It is now regarded as *Dusisiren jordani* (Domning, 1978: 21). In summary, “*M. petersi*” has not been reliably recorded outside of Austria. It remains to be determined whether it can be

regarded as a distinct species even within our study area.

### 7.2 VALIDITY OF “*METAXYTHERIUM PETERSI*”

The distinctiveness of *Metaxytherium* (or *Thalattosiren*) *petersi* has been defended by several authors. Abel (1904), who originally named *M. petersi* and regarded it as representing a lineage distinct from other *Metaxytherium*, unfortunately had little but isolated teeth and postcranial elements of this species to study, and these were mostly referred specimens; the holotype from Hainburg lacked the skull and was of little diagnostic use. He compared them almost exclusively with *M. krahuletzki*, and in the few instances where he was able to make the more relevant comparisons with the coeval *M. medium* (his “*M. cuvieri*”) he found practically no differences. Neither did he give an explicit diagnosis of *M. petersi*, but for the most part merely pointed out contrasts with other species in the course of his description. Among these, the following distinctions from other Miocene *Metaxytherium* seem to have struck him as most important:

- Lower molars more quadratic, with more numerous secondary cuspules but (on m3) a less developed hypoconulid than in *M. krahuletzki*
- Scapula with ridge extending from dorsal end of spine to anterodorsal corner of scapula; blade narrower, with broadest portion of supraspinous fossa located more distally than in *M. krahuletzki*, and spine reaching closer to glenoid
- Tubercles of humerus larger relative to head than in *M. krahuletzki*; head with flatter curvature; greater and lesser tubercles in proximal view form angle of 80°, compared with 55° in *M. krahuletzki* and 85°-90° in *M. medium*; greater tubercle reaching higher (i.e., farther proximally) than head (unlike *M. krahuletzki* but like *M. medium*); entepicondyle “lies [anteroposteriorly] closer to the [distal] joint surface” than in *M. krahuletzki*; diaphysis strongly constricted just above anterior border of trochlea
- Posterior edge of distal part of ulna rounded, not sharp as in *M. krahuletzki*; torsion between radius and ulna less than in either *M. krahuletzki* or *M. medium*

Sickenberg (1927; 1928: 320-321), having at last a good skull to study, still did not give a formal diagnosis, but mentioned the following characters as distinctive, emphasizing “the unusual combination of relative simplicity of the tooth structure and high specialization of the skull” as justifying the erection of the new genus *Thalattosiren*:

- Braincase broadened, shortened
- Rostral deflection strong
- Well-developed nasal bones retained
- Molars simple, relatively lophodont

Later, however, Sickenberg (in Pia and Sickenberg, 1934: 403) abandoned the name *Thalattosiren* and explicitly returned to consistent use of the combination *Metaxytherium petersi*, though without giving reasons. Thenius (1952: 109-110) surmised that Sickenberg had simply come to a more inclusive concept of the genus *Metaxytherium*, taking into account its observed variability (although Thenius himself evidently did



not agree, since he continued to use *Thalattosiren*). Thenius (1952: 112) then went on to list explicitly the chief characters that for him distinguished *Thalattosiren* from *Metaxytherium*:

- Braincase broader, more shortened
- Rostral deflection stronger
- Nasal bones well developed
- Molars simpler, lophodont
- Incisor tusks possibly lacking

We shall consider these alleged differences individually:

- Stronger rostral deflection: The rostral deflection of the St. Margarethen "*Thalattosiren*" skull (BLLM 32816) is 55°, which is comparable to or less than the deflections seen in *Metaxytherium*: e.g., *M. cf. krahuletzii*, estimated 60° (Sorbi, 2008b); *M. medium*, ca. 50° (as seen in "*M. catalaunicum*" of Pilleri et al., 1989, and the specimen of Moncharmont-Zei and Moncharmont, 1987, measured by Domning); *M. serresii*, 50°-73° (Carone and Domning, 2007); *M. subappenninum*, 57°-63° (Sorbi et al., 2012); *M. floridanum*, 64°-81° (Domning, 1988; Carone and Domning, 2007); *M. arcotodites*, 71° (Aranda-Manteca et al., 1994). Therefore, the view of Sickenberg (1928) and Thenius (1952) that *Metaxytherium* characteristically has a less deflected snout than *Thalattosiren* was a mistaken impression occasioned by their lack of data on well-preserved skulls of *Metaxytherium*. The rostral deflection of the St. Margarethen specimen is probably not outside the range of variation to be expected in *M. medium*.
- Possible lack of incisor tusks: No trace of tusk alveoli is visible in BLLM 32816 or NHMW 2007z0106/0001, but in each case an unknown length is missing from the tip of the rostrum. If tusks were present, they were at least as small as in other Early and Middle Miocene *Metaxytherium*, and absence of tusks cannot be ruled out. Both skulls are juvenile (see below), so the tusks (if present) would have consisted of little but the developing and unerupted crown (cf. *M. floridanum*, Domning, 1988: 409). The Gainfarn specimen lacks the premaxillae and sheds no new light.
- Well-developed nasal bones: The nasals of BLLM 32816 are indeed very large compared to known *Metaxytherium*, and are in contact in the midline for a length greater than 1 cm [c. 31(0)], whereas in most *Metaxytherium* they are completely separated in the midline [c. 31(1)]. However, there are exceptions: the nasals were possibly in midline contact in some *M. krahuletzii* (Domning and Pervesler, 2001), and were in contact in one or two out of five *M. serresii* (Carone and Domning, 2007). Pilleri, in describing his nominal species "*M. catalaunicum*", illustrated it (in Pilleri et al., 1989: fig. 33b) as questionably having large, conjoined nasals, though he did not comment on this feature (and we have not seen the specimen). Even in the Recent and much more derived dugongid *Hydrodamalis gigas*, vestigial but nonetheless conjoined nasals can occur (Brandt, 1868: pl. 1, fig. 5). Therefore it seems possible that, in a species with otherwise reduced and separated nasals such as *M. medium*, occasional atavistic individuals with much larger and consequently conjoined nasals might occur. Furthermore, no Neogene dugongid taxon other than "*Thalattosiren*" is known to have had large, conjoined nasals; and this makes the existence of a Middle Miocene genus with this characteristic unexpected and doubtful *a priori*.
- Broader, more shortened braincase: This is the most visually-striking distinction between BLLM 32816 and other *Metaxytherium*. However, it is a characteristic of juvenile mammals in general; and BLLM 32816 is clearly immature, as shown by its open basioccipital-basisphenoid suture; DP2 alveolus, DP3-5, and M1 present; and M2 unerupted (Dp3-M2 were respectively identified as P<sup>3</sup>, d4, and M<sup>1-3</sup> by Sickenberg, 1928). NHMW 2007z0106/0001 is an even younger juvenile, with an open basioccipital-basisphenoid suture and spacious dental capsules for still-forming molars, in addition to being much smaller than BLLM 32816 and similar in size and proportions to a juvenile *M. krahuletzii* (KÜH 88; Domning and Pervesler, 2001). The still smaller MAFI juvenile from Fazekasboda (Table 2) has the shortest parietals relative to their width of any of these specimens. However, the Müllendorf skull, with the smallest dimensions of all, has a narrower, more rectangular parietal roof like more mature specimens. Hence individual variation may be a confounding factor here.
- Molars lophodont, simpler: The dental comparisons of previous workers were hampered by small samples and faulty understanding of dental homologies. Sickenberg (1928), followed by Thenius (1952), misinterpreted the dentition of the St. Margarethen skull. The first four teeth in its upper toothrow in fact correspond to those of a juvenile *M. floridanum* (Domning, 1988: fig. 8A); i.e., DP3-5 and M1. The latter do not differ materially from the Austrian form in complexity of cusp pattern or degree of lophodonty; thus there is no basis in these features for a generic distinction. Sickenberg's belief that M1-2 of his specimen were instead M2-3 may have led him to think they should have more complex patterns if they were to represent *Metaxytherium*. M3 is often larger and more complex in other *Metaxytherium*, but not always, and the homology was mistaken in any case.
- Lower molars more quadratic, with more numerous secondary cuspules but a less developed m3 hypoconulid than in *M. krahuletzii*: Having only isolated teeth of *M. krahuletzii* and "*M. petersi*" to work with, Abel (1904: 112) called particular attention to an unworn specimen (Peters, 1867: pl. 7, fig. 2; Abel, 1904: pl. 1, fig. 18) that clearly is more quadratic and with a smaller hypoconulid than the worn m3 of *M. krahuletzii* shown in his pl. 1, fig. 20. However, the former is not m3 (as is clear from its lack of an enlarged posterior root; Abel, 1904: 111) but a more anterior molar, which accounts for the difference in shape; and its unworn condition could account for the numerous secondary cuspules (whose distinctness would be obscured by moderate wear like that of the latter tooth).
- Scapula with ridge from dorsal end of spine to anterodorsal

corner: This peculiarity of the holotype of *M. petersi* is unique among known sirenians, and is not observed in the 2006 Gainfarn specimen. Without corroboration it is not advisable to base a taxonomic distinction on it, as it may be just an individual anomaly of the m. supraspinatus attachment. In fact, it bears a distinct resemblance to an elevated area at the dorsal end of the spine in a scapula of *M. subapenninum* (= "*Felsinotherium Forestii*"; compare Abel, 1904: pl. 2, figs. 6 and 7).

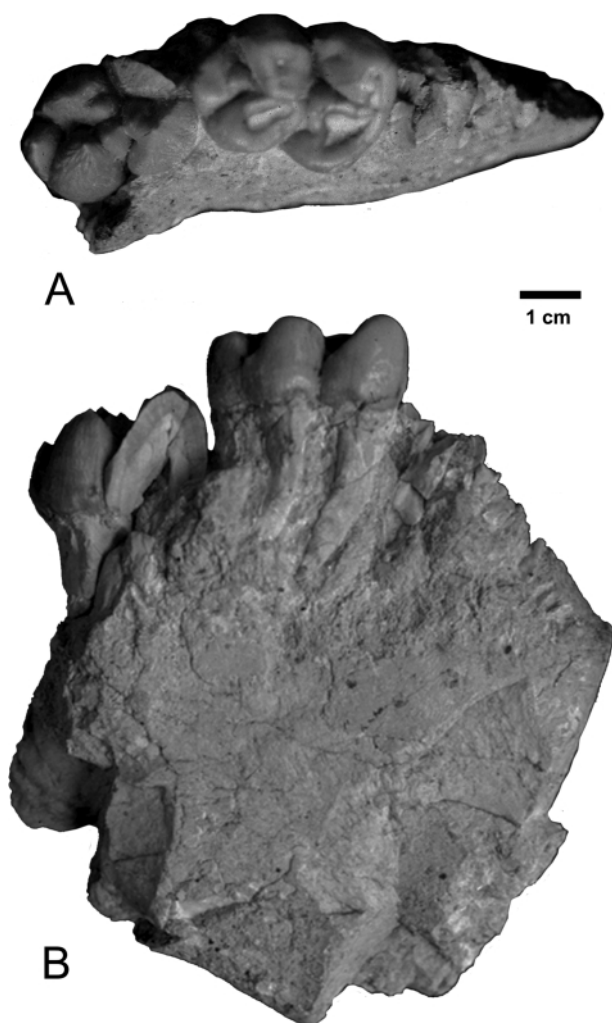
- Supraspinous fossa differently shaped, with scapular spine reaching closer to glenoid: The better sample of *M. krahuletzki* available today shows that the differences from the Hainburg specimen noted by Abel are merely individual ones. In fact, his two forms of the supraspinous fossa are almost matched on the two sides of a single specimen (Domning and Pervesler, 2001: pl. 15)! In a specimen of *M. medium* (Monchamont Zei and Monchamont, 1987: pl. 12), the fossa is intermediate but closer in shape to that of the Hainburg scapula. (The scapula of the St. Margarethen specimen BLLM 32816 was not described by Sickenberg, but its outline, preserved as an impression in matrix, resembles that of the Hainburg scapula.) As for the location of the distal end of the spine, it is difficult to discern any difference between the nominal species, even in Abel's own illustrations.
- Humeral tubercles larger relative to head; greater tubercle reaching farther proximally: Of the specimens studied by Abel (1904: pl. 4), the tubercles and other parts of the humerus he assigned to *M. petersi* are indeed more robust; however, the present sample of *M. krahuletzki* includes similarly robust forms (Domning and Pervesler, 2001: pls. 16-17), as does *M. medium*. The greater tubercle in *M. krahuletzki* usually extends well proximad of the head (Domning and Pervesler, 2001: 36, pl. 16), and this is also the norm in *M. medium* (e.g., Monchamont Zei and Monchamont, 1987: pl. 13) and other species of the genus, including the Gainfarn specimen.
- Greater and lesser tubercles of humerus more nearly perpendicular: This seems to characterize later species of *Metaxytherium* more than earlier ones, but is variable in those that have been adequately sampled: for example, the angle between the axes of the tubercles is approximately 60°-85° in the Early Miocene *M. krahuletzki* (Domning and Pervesler, 2001), and 75°-90° in the late Middle Miocene *M. florida-num* (Domning, 1988). Three Middle Miocene *M. medium* from France measure approximately 78°-95° (Domning, unpublished data). The value reported for "*M. petersi*" (Abel, 1904: 119) and that of the Gainfarn specimen are both 80°; that of the Marz specimen MAFI Ob-3036 is ~90°. Therefore, even if a trend toward greater values exists, it is of scant use in identifying individual specimens or distinguishing species.
- Humeral head with flatter curvature: This is true of the Gainfarn specimen. However, in contrast to the Kalksburg specimen described by Abel (1904: pl. 4, fig. 5b,c), the holotype of *M. petersi* does not have a flatter curvature (Peters, 1867: pl. 7, fig. 6a,c); hence this trait, evidently varying among individuals, does not reliably characterize the species.
- Humerus with entepicondyle closer to trochlea, and diaphysis more constricted above trochlea: Based on larger samples than were available to Abel (1904), these features likewise appear to be individually variable.
- Ulna with less sharp posterior edge; less torsion between ulna and radius: The former distinction is true of the Gainfarn specimen, but the latter is not. The degree of torsion is variable in *M. krahuletzki* (Domning and Pervesler, 2001: 36-37); Abel (1904: 175) says only that in *M. petersi* it is "still less" than in the latter, which in turn shows less torsion than *M. medium* (= *cuvieri*). Since this observation was based only on a distal radius-ulna from Kalksburg, of which the ulnar part had apparently been lost by the time of Pia and Sickenberg (1934: no. 3342), no corroboration or quantification can now be provided. It is probable that these features of "*M. petersi*" would fall within the range of variation of *M. medium* and other species.

In summary, we conclude that when individual and ontogenetic variation are taken fully into account, there remains no convincing basis for separating the *Metaxytherium* of the Vienna and neighboring basins from the contemporary Western European and Mediterranean *M. medium* at the specific, let alone the generic level. Certainly there is no reliable basis for a differential diagnosis of *M. petersi*, let alone *Thalattosiren*. The holotype of *M. petersi* was inadequately diagnostic even before parts of it were lost; hence we have had to base our conclusions on broadly "topotypic" specimens (i.e., the entire sample of Badenian age from the Vienna and neighboring basins). Neither individually nor collectively do these show evidence of distinction from *M. medium*. We therefore formally synonymize *M. petersi* Abel with *M. medium* (Desmarest).

### 7.3 VALIDITY OF HAPLOSIREN LEGANYII

One more nominal taxon from the Badenian of the Central Paratethys is *Haplosiren leganyii* from Hungary, described by Kretzoi (1951) but not illustrated (Thenius [1952] considered it a nomen nudum). The sole specimen is a fragment of an immature left mandible containing m2-3 and the roots of dp4-5 and m1 (Fig. 11). It is very large, its molars being within the size range of *Metaxytherium subapenninum* or (in the case of m2) even larger. It is also larger than the dugongine *Rytiodus heali* (Domning and Sorbi, 2011), and has no special resemblance to it that would suggest *Haplosiren* is other than a halitheriine. The m2 is moderately worn; m3 is unworn and just beginning to erupt. Its posterior root is not elongated antero-posteriorly, but has a longitudinal ridge on its posterior surface (as m2 may have also). The cusp pattern is typical of *Metaxytherium*, and surprisingly simple, as Kretzoi noted and the name *Haplosiren* denotes. The hypolophids each have two cusps placed anteriorly toward the midline of the tooth. Each molar has a single large hypoconulid cusp; on m2 this has a small cuspsule on its anterior side. Otherwise there are

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe



**FIGURE 11:** (MAFI V.10973), left mandibular fragment with m2-3. A: dorsal (occlusal) view. B: medial view.

no accessory cuspules. The unworn cusps have sharp tips, and the enamel (which is up to 3 mm thick near a cusp apex) is wrinkled where not worn smooth. A "vorderes Basalband" (sensu Abel, 1904) is present on the anterolabial corner of m2.

In comparison with *Metaxytherium* from the Central Paratethys, the teeth of *Haplosiren leganyii* are only slightly larger than some isolated m3s from the Vienna Basin, although none of the m2s yet collected from there match the Hungarian specimen in size (Tables 4, 5). It is possible for even very large m3s of *Metaxytherium* to have a single-cusped hypoconulid, as shown by *M. floridanum* (Domning, 1988: fig. 8H; crown length of USNM 359703 = 31.9 mm). The wrinkled enamel on m3 of the Hungarian form, however, is a peculiarity not previously noted in a dugongid.

Domning and Thomas (1987) tentatively regarded *Haplosiren leganyii* as a synonym of *Metaxytherium medium*. Despite its unusual size, simple molars, and wrinkled enamel, this is still a possible interpretation of this possibly aberrant individual. A conceivable alternative would be the late Badenian immigration of a different taxon, possibly even a dugongine, from the Indopacific. (An analogous Mediterranean-Indopacific connection in the late Oligocene was cited to explain the distribution of

some fossil cetaceans by Bianucci et al., 2011.) However the Indopacific sirenians of the late Badenian still remain unknown.

### 7.3 IMPLICATIONS OF RECOGNITION OF CENTRAL PARATETHYAN *METAXYTHERIUM MEDIUM*

These conclusions expand the known geographic range of *M. medium*, and also the species' known morphological sample. This is of particular interest in regard to the sternum, an element hitherto not well represented in this species, but possibly useful in distinguishing *M. medium* from *M. krahuletzii* (Domning and Pervesler, 2001: 44, pl. 14). The latter species has a long sternum with three parts (a primitive condition); these fuse in the adult, and are all about equally narrow. At least some later species, including *M. serresii* and *M. floridanum*, have shorter sterna that are broader in their middle and sometimes anterior portions, and comprise no more than two elements. Evidence concerning *M. medium*, however, is scanty and ambiguous. The Gainfarn sternum (Fig. 8A), the best-preserved example to date, is scarcely wider than in *M. krahuletzii*; and although its fusion of the two anterior elements can be seen as a resemblance to *M. medium*, this condition would hardly be surprising if found in *M. krahuletzii*, given the great individual variability customarily seen in sirenian sterna. On the whole, the Gainfarn specimen seems to indicate that *M. medium* and *M. krahuletzii* shared the same sternal morphology.

As for the stratigraphic range of *M. medium*, this is regarded as extending from approximately the beginning of the Langhian into the late Tortonian (Sorbi et al., 2012:fig. 12B). The Badenian correlates with the Langhian and the early part of the Serravallian; therefore the specimens reported here (the earliest of which is "?early to middle Badenian"; Table 1) do not extend the known chronological range of the species. Neither do they provide a more precise datum for the first appearance of the species – especially since they are mostly fragmentary, and the distinction between *M. krahuletzii* and *M. medium* is problematical even given good material (Domning and Pervesler, 2001:43-45). Bianucci et al. (2003:table 1) provide a table of *Metaxytherium* records from the Miocene (Burdigalian-Tortonian) of the Mediterranean basin; these are mostly not determined to species, but with the addition of the present evidence, they justify the conclusion of Bianucci et al. (2003) that *M. medium* had a very wide distribution in Europe, stratigraphical as well as geographical.

The synonymization of *M. petersi* with *M. medium* further corroborates the hypothesis (e.g., Sorbi et al., 2012) that the Old World *Metaxytherium* comprise an unbranched anagenetic series of chronospecies. Interestingly, this tends to support a comment of Abel (in Sickenberg, 1927: 106, concerning the discovery of the St. Margarethen skull) that in the case of the Sirenia we are able – sometimes, at least – to observe the evolutionary stages in a direct line of descent, "and not, as usual, just side branches"!

### 8. PALEOZOOGEOGRAPHY AND PALEOECOLOGY

Although we conclude that taxonomic separation of these



Paratethyan animals from their contemporary *Metaxytherium medium* is not justified, the fact that they have been so separated in the past draws attention to their peculiar zoogeographic circumstances, which are in fact such that taxonomic differentiation would not have been surprising. During the course of the Badenian, the portion of Paratethys that included the Vienna, Eisenstadt-Sopron, and Styrian Basins became sporadically but progressively cut off from the Indopacific and/or Mediterranean Sea, respectively to the southeast and southwest, until by the late Badenian and Sarmatian they formed a virtually landlocked sea (Rögl and Steininger, 1983; Rögl, 1999; Meulenkamp and Sissingh, 2003; Bianucci et al. 2011). Their sirenian inhabitants would then have been reproductively isolated from other populations of *M. medium*, and given enough time, this marginal isolate could well have evolved into a separate species. At the least, considering the basin's environmental changes, we might expect some genetic and morphological peculiarities to have appeared in it, which could possibly account for the unusual features of a form like *Haplosiren leganyii*. If such differences never attained the level of taxonomic differentiation, it may be because this isolated population soon went extinct – if by Sarmatian time the Vienna and Pannonian Basins became too low in salinity (Harzhauser and Piller, 2007) for the seacows (or the seagrasses they depended on) to tolerate.

The data on the Central Paratethyan *Metaxytherium medium* presented above permit some inferences about its mode of life. As with the Eggenburgian *M. krahuletzii* (compare Domning and Pervesler, 2001), relationships and gross similarities to the Recent dugongids *Dugong* and *Hydrodamalis* suggest that, like them, the seacows of Badenian age from the Vienna, Styrian, and Eisenstadt-Sopron Basins dwelt exclusively in shallow marine waters. The co-occurrence of diagnostic shallow marine faunas points to a transition from humid, tropical shallow subtidal biotopes in the early early Badenian (16.26-14.89 Myr) to a subtropical climate in the Middle Badenian (14.89-13.82 Myr) to warm temperate climate during late Badenian (13.82-12.73 Myr) (Hohenegger et al., 2008). Such reasoning points to tropical to warm temperate climatic tolerances and a diet of seagrasses (cf. Domning, 2001), the presence of which at Gainfarn was inferred by Zuschin et al. (2007).

The rostral deflection from the occlusal plane of the St. Margarethen skull (BLLM 32816) is 55°, which is comparable to or less than the deflections seen in other *Metaxytherium* (see above) but less than that of the bottom-feeding *Dugong* (circa 70°). Probably *M. medium* was an obligate consumer of benthic plants (Domning, 2001) like most halitheriines and dugongines.

The presence of tusks cannot be proven; no trace of tusk alveoli is preserved in BLLM 32816 or NHMW 2007z0106/0001. Small tusks were, however, possessed by other *M. medium*, and they were presumably present in these Central European populations as well. The effect on feeding strategies of lacking larger tusks might have been the avoidance of large and tough seagrass rhizomes. Presumably the Badenian seacows

ate seagrass leaves, shoots, and the more delicate and less deeply buried rhizomes, as the tuskless manatees (*Trichechus*) do today (e.g., Packard, 1984). In contrast to the large-tusked dugongines like *Rytiodus*, the more common though seemingly less diverse halitheriines like *Metaxytherium* with smaller tusks were probably ecological generalists.

On the other hand, the fact that *M. medium* had large, complex, well-enameled molariform teeth shows that it was not restricted to the most delicate, least fibrous seagrasses, as the modern *Dugong* (with its degenerate cheek teeth that lack functional enamel crowns) largely is (Lanyon, 1991).

In conclusion, *Metaxytherium medium* was a halitheriine dugongid distributed throughout the marine waters of the Central Paratethys, other parts of Europe, and presumably North Africa during the Middle Miocene. It was an ecological generalist that probably fed on the leaves and rhizomes of small and medium-sized benthic seagrasses. Its fossil record in the Central Paratethys ends with the Badenian, but its lineage continued in the Mediterranean into the late Pliocene.

#### ACKNOWLEDGEMENTS

The study was supported by the Department of Palaeontology at the University of Vienna. The excavation in Gainfarn was made possible by the permission of K. Lindenberg (Enzesfeld-Lindabrunn) and his family to perform the excavation on their property. Many thanks go to the collector G. Wanzenböck (Bad Vöslau) who discovered the Gainfarn specimen and together with H. Hobik, V. Perlinger (University of Vienna) and F. Mayer (University of Vienna) did the main part of the recovery. We extend our special thanks to the municipality of Bad Vöslau, its mayor Christoph Prinz and all members of his staff for their support. Special thanks also are due to S. Corić (Geological Survey of Austria), M. Harzhauser (Museum of Natural History, Vienna), J. Hohenegger (University of Vienna), R. Lein (University of Vienna), R. Roetzel (Geological Survey of Austria), F. Rögl (Museum of Natural History, Vienna) and G. Wessely (OMV), for providing information on the stratigraphic and topographic position of seacow sites in eastern Austria. Information on inventory numbers was provided by A. Kroh (Museum of Natural History, Vienna) and K. Rauscher (University of Vienna). U. Göhlich (Museum of Natural History, Vienna), S. Ebster (Stadtmuseum Bad Vöslau), M. Tschach (Burgenländisches Landesmuseum, Eisenstadt), I. Zorn (Geological Survey of Austria), and L. Kordos (Geological Survey of Hungary) enabled us to study those collections. Photos of the juvenile seacow skull NHMW 2007z0106/0001 were done by A. Schuhmacher (Museum of Natural History, Vienna). A. Simms (Howard University) assisted with Fig. 10.

#### REFERENCES

Abel, O., 1904. Die Sirenen der mediterranen Tertiärbildungen Oesterreichs. Abhandlungen der k.k. geologischen Reichsanstalt Wien, 19, 1-223.

- Abel, O., 1913. Die eocänen Sirenen der Mittelmeerregion. Erster Teil: Der Schädel von *Eotherium aegyptiacum*. *Palaeontographica* 59, 289-360.
- Abel, O., 1928. Parasitische Balanen auf Stockkorallen aus dem Miozänmeer. *Paläobiologica*, 1, 13-38.
- Aranda-Manteca, F. J., Domning, D. P. and Barnes, L. G., 1994. A new Middle Miocene sirenian of the genus *Metaxytherium* from Baja California and California: relationships and paleobiogeographic implications. *Proceedings of the San Diego Society of Natural History*, 29, 191-204.
- Bajpai, S. and Domning, D.P., 1997. A new dugongine sirenian from the Early Miocene of India. *Journal of Vertebrate Palaeontology*, 17, 219-228.
- Bianucci, G., Carone, G., Domning, D.P., Landini, W., Rook, L. and Sorbi S., 2008. Peri-Messinian dwarfing in Mediterranean *Metaxytherium* (Mammalia: Sirenia): evidence of habitat degradation related to the Messinian salinity crisis. *Garyounis Scientific Bulletin, Special Issue*, 5, 145-157.
- Bianucci, G., Gatt, M., Catanzariti, R., Sorbi, S., Bonavia, C. G., Curmi, R. and Varola, A., 2011. Systematics, biostratigraphy and evolutionary pattern of the Oligo-Miocene marine mammals from the Maltese Islands. *Geobios*, 44, 549-585.
- Bianucci, G., Landini, W. and Varola, A., 2003. New records of *Metaxytherium* (Mammalia: Sirenia) from the Late Miocene of Cisterna quarry (Apulia, southern Italy). *Bollettino della Società Paleontologica Italiana*, 42, 59-63.
- Blainville, H.M. Ducrotay de, 1844. *Ostéographie ou description iconographique comparée du squelette et du système dentaire des mammifères récent et fossiles pour servir de base à la zoologie et à la géologie*. [Livr. 15] Des lamantins (Buffon), (Manatus, Scopoli), ou gravigrades aquatiques. Paris, Arthus Bertrand (4 vols. + 4 vol. atlas): Vol. 3, Livr. 15: 1-140.
- Brandt, J. F., 1868. *Symbolae sirenologicae. Fasciculi II et III. Sireniorum, Pachydermatum, Zeuglodontum et Cetaceorum ordinis osteologia comparata, nec non Sireniorum generum monographie. Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg*, 12(1), 1-384.
- Carone, G. and Domning, D.P. 2007. *Metaxytherium serresii* (Mammalia: Sirenia): new pre-Pliocene record, and implications for Mediterranean paleoecology before and after the Messinian Salinity Crisis. *Bollettino della Società Paleontologica Italiana*, 46(1), 55-92.
- Carus, J.V., 1868. *Handbuch der Zoologie. 1ster Band. Wirbelthiere, Mollusken und Molluscoiden*. Leipzig, Wilhelm Engelmann, ix + 894.
- Christol, J. de, 1840. Recherches sur divers ossements fossiles attribués par Cuvier à deux phoques, au lamantin, et à deux espèces d'hippopotames, et rapportés au *Metaxytherium*, nouveau genre de cétacé de la famille des dugongs. *L'Institut Annales*, 8, 322-323.
- Cuvier, G., 1821. *Recherches sur les ossements fossiles de quadrupèdes*, ed. 2, vol. 1.
- Czyżewska, T. and Radwański, A., 1991. Middle Miocene (Badenian) delphinid and phocoenid remains from the Fore-Carpathian Depression in southern Poland. *Acta Geologica Polonica*, 41(3-4), 183-191.
- Decker, K. and Peresson, H., 1996. Tertiary kinematics in the Alpine-Carpathian-Pannonian System: links between thrusting, transform faulting and crustal extension. In: Wessely, G., and Liebl, W., (eds.), *Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe*, EAPG Special Publications 5, 69-77.
- Decker, K., Peresson, H. and Hinsch, R., 2005. Active tectonics and Quaternary basin formation along the Vienna Basin Transfer fault. *Quaternary Science Reviews*, 24, 305-320.
- Depéret, Ch., 1895. Über die Fauna von miocänen Wirbelthieren aus der ersten Mediterranstufe von Eggenburg. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Classe*, 104(1), 395-416.
- Depéret, C. and Roman, F., 1920. *Le Felsinotherium serresii* des sables pliocènes de Montpellier et les rameaux phylétiques des siréniens fossiles de l'Ancien Monde. *Archives du Muséum d'histoire naturelle de Lyon*, 12(4), 1-56.
- Desmarest, A.C., 1822. *Mammalogie ou description des especes de Mammifères*. *Encyclopédie méthodique*, 126, Paris, 1-555.
- Domning, D.P., 1977. An ecological model for Late Tertiary sirenian evolution in the North Pacific Ocean. *Systematic Zoology*, 25(4), 352-362.
- Domning, D.P., 1978. Sirenian evolution in the North Pacific Ocean. *University of California Publications in Geological Sciences*, 118, xi + 176.
- Domning, D.P., 1988. Fossil Sirenia of the West Atlantic and Caribbean region. I. *Metaxytherium floridanum* Hay, 1922. *Journal of Vertebrate Palaeontology*, 8, 395-426.
- Domning, D.P., 1989. Kelp evolution: a comment. *Paleobiology*, 15(1), 53-56.
- Domning, D.P., 1990. Sirenian rhizivory studies. In: L. W. Lefebvre & J. A. Powell, Jr., *Manatee grazing impacts on seagrasses in Hobe Sound and Jupiter Sound in southeast Florida during the winter of 1988-89*. *National Technical Information Service Document*, PB 90-271883 (vi + 36), 34-36.

- Domning, D. P., 1994a. A phylogenetic analysis of the Sirenia. *Proceedings of the San Diego Society of Natural History*, 29, 177-189.
- Domning, D.P., 1994b. West Indian tuskers. *Natural History*, 103(4), 72-73.
- Domning, D.P., 1996. Bibliography and index of the Sirenia and Desmostylia. *Smithsonian Contributions to Paleobiology*, 80, iii + 611.
- Domning, D.P., 2001. Sirenians, seagrasses, and Cenozoic ecological change in the Caribbean. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 166, 27-50.
- Domning, D.P., 2010. Bibliography and Index of the Sirenia and Desmostylia, [www.sirenian.org/biblio](http://www.sirenian.org/biblio).
- Domning, D.P. and Aguilera, O. A., 2008. Fossil Sirenia of the West Atlantic and Caribbean region. VIII. *Nanosiren garciae*, gen. et sp. nov. and *Nanosiren sanchezi*, sp. nov. *Journal of Vertebrate Paleontology*, 28(2), 479-500.
- Domning, D.P. and Sorbi, S., 2011. *Rytiodus heali*, sp. nov., a new sirenian (Mammalia: Dugonginae) from the Miocene of Libya. *Journal of Vertebrate Paleontology*, 31(6), 1338-1355.
- Domning, D.P. and Thomas, H., 1987. *Metaxytherium serresii* (Mammalia: Sirenia) from the early Pliocene of Libya and France: a reevaluation of its morphology, phyletic position, and biostratigraphic and paleoecological significance. In: Boaz, El-Arnauti, Gaziry, de Heinzelin, and Boaz (eds.), *Neogene paleontology and geology of Sahabi*, pp. 205-232, New York (Liss).
- Domning, D.P. and Pervesler, P., 2001. The Osteology and Relationships of *Metaxytherium krahuletzii* DEPÉRET, 1895 (Mammalia: Sirenia). *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*, 553, 1-89.
- Dullo, W.-Ch., 1983. Fossildiagenese im miozänen Leitha-Kalk der Paratethys von Österreich: Ein Beispiel für Faunerverschiebungen durch Diageneseunterschiede. *Facies*, 8, 1-112.
- Ehrenberg, K., 1927. Bestimmung der Knochenreste von Friedberg nebst einigen Bemerkungen über dieselben. *Verhandlungen der Geologischen Bundesanstalt, Wien*, 1927(4), 103-106.
- Friebe, J.G., 1988. Paläogeographische Überlegungen zu den Leithakalkkarealen (Badenien) der Mittelsteirischen Schwelle (Steiermark). *Geologisch Paläontologische Mitteilungen Innsbruck*, 15, 41-57.
- Friebe, J.G., 1990. Lithostratigraphische Neugliederung und Sedimentologie der Ablagerungen des Badenium (Miozän) um die Mittelsteirische Schwelle (Steirisches Becken, Österreich). *Jahrbuch der Geologischen Bundesanstalt*, 133, 223-257.
- Frisch, W., Dunkl, I. and Kuhlemann, J., 2000. Post-collisional orogen-parallel large-scale extension in the Eastern Alps. *Tectonophysics*, 327, 239-265.
- Fuchs, Th., 1869. Der Steinbruch im marinen Conglomerate von Kalksburg und seine Fauna, mit einer Einleitung über die Darstellung von Local-Faunen. *Jahrbuch der k.k. Geologischen Reichsanstalt*, 19, 190-195.
- Gray, J.E., 1821. On the natural arrangement of vertebrate animals. *London Med. Reposit.* 15(88), 296-310.
- Hamilton, W., Wagner, L. and Wessely, G., 2000. Oil and gas in Austria. *Mitteilungen der Österreichischen Geologischen Gesellschaft*, 92, 235-262.
- Handler, R., Ebner, F., Neubauer, F., Bojar, A. and Hermann, S., 2006.  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of Miocene tuffs from the Styrian part of the Pannonian Basin: an attempt to refine the basin stratigraphy. *Geologica Carpathica*, 57, 483-494.
- Harzhauser, M. and Piller, W. E., 2004a. The Early Sarmatian - hidden seesaw changes. *Courier Forschungsinstitut Senckenberg*, 246, 89-112.
- Harzhauser, M. and Piller, W. E., 2004b. Integrated Stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys. *Stratigraphy* 1, 65-86.
- Harzhauser, M. and Piller, W. E., 2007. Benchmark data of a changing sea - Palaeogeography, Palaeobiogeography and events in the Central Paratethys during the Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 253, 8-31.
- Hauer, F., 1867. *Halianassa collini* aus einer Sandgrube bei Hainburg. *Verhandlungen der Geologischen Reichsanstalt Wien*, 1867(7), 140-141.
- Hauer, F., 1886. Jahresbericht für 1885. *Annalen des k.k. Naturhistorischen Hofmuseums*.
- Heal, G. J., 1973. Contributions to the study of sirenian evolution. Ph.D. thesis, University of Bristol, England (unpubl.).
- Hinsch, R., Decker, K. and Peresson, H., 2005. 3-D seismic interpretation and structural modeling in the Vienna Basin: Implications for Miocene to Recent kinematics. *Austrian Journal of Earth Sciences*, 97, 38-50.
- Hohenegger, J., Coric, S., Khatun, M., Pervesler, P., Rögl, F., Rupp, Ch., Selge, A., Uchman, A. and Wagreeich, M., 2008. Cyclostratigraphic dating in the Lower Badenian (Middle Miocene) of the Vienna Basin (Austria): the Baden-Sooss core. *International Journal of Earth Sciences*, 98, 915-930.
- Hohenegger, J., Pervesler, P., Uchman, A. and Wagreeich, M., 2009. Upper bathyal trace fossils document palaeoclimate changes. *Terra Nova: the European Journal of Geosciences*, 21, 229-236.



- Hohenegger, J., Ćorić, S. and Wagreich, M., 2011. Beginning and division of the Badenian stage (Middle Miocene, Paratethys). In Bąk, M., Kaminski, M.A. and A. Waśkowska (eds.). Integrating Microfossil Records from the Oceans and Epicontinental Seas. Grzybowski Foundation Special Publication, 17, Part 2. Abstracts of the Eighth Micropalaeontological Workshop "MIKRO-2011" and TMS Foraminiferal-Nannofossil Group Annual Meeting, 92-93.
- Hohenegger, J. and Wagreich, M., 2012. Time calibration of sedimentary sections based on insolation cycles using combined cross-correlation: dating the gone Badenian stratotype (Middle Miocene, Paratethys, Vienna Basin, Austria) as an example. *International Journal of Earth Sciences*, 101, 339-349.
- Hörnes, M., 1848. 3. Versammlung, am 18. Februar. Jahrbuch für Mineralogie und Mitteilungen der Freunde der Naturwissenschaften in Wien, 1848, 176-178.
- Hooijer, D., 1952. Fact and fiction in hippopotamology (sampling the history of scientific error). *Osiris*, 10, 109-116.
- Illiger, C., 1811. *Prodromus systematis mammalium et avium additis terminis zoographicis utriusque classis, eorumque versione Germanica*. Berlin, sumptibus C. Salfeld, xviii + 302.
- Karrer, F., 1877. *Geologie der Kaiser Franz Josef Hochquellen-Wasserleitung*. Abhandlungen der k.k. geologischen Reichsanstalt, 9, i-xiii, 1-420, 20 plates.
- Kováč, M., Baráth, I., Harzhauser, M., Hlavatý, I., and Hudácková, N., 2004. Miocene depositional systems and sequence stratigraphy of the Vienna Basin. *Courier Forschungsinstitut Senckenberg*, 246, 187-212.
- Kováč, M., Holcová, K. and Nagymarosy, A., 1999. Paleogeography, paleobathymetry and relative sea-level changes in the Slovakian Danube Basin and adjacent areas. *Geologica Carpathica*, 50, 1-13.
- Kretzoi, M., 1951. Új sziréna-típus a Magyar Miocénből. (Neuer Sirenen-Typus aus dem ungarischen Miozän.) *Földtany Közlöny*, 81(10-12), 438-441.
- Lanyon, J.M., 1991. The nutritional ecology of the dugong, *Dugong dugon*, in tropical north Queensland. PhD thesis, Monash University.
- Linnaeus, C., 1758. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Tomus I. Editio decima, reformata. Holmiae (= Stockholm), Laurentii Salvii: (10) + 11-532.
- Meulenkamp, J.E., Sissingh, W., 2003. Tertiary palaeogeography and tectonostratigraphic evolution of the northern and southern Peri-Tethys platforms and the intermediate domains of the African-Eurasian convergent plate boundary zone. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 196, 209-228.
- Moncharmont-Zei, M. and Moncharmont, U., 1987. Il *Metaxytherium medium* (Desmarest) 1822 (Sirenia, Mammalia) delle arenarie tortoniane (Miocene sup.) di San Domenica di Ricadi (Catanzaro, Italia). *Memorie di Scienze Geologiche Padova*, 39, 285-341.
- Muizon, C., de and Domning D.P., 1985. The first records of fossil sirenians in the southeastern Pacific Ocean. *Bulletin du Muséum National d'Histoire Naturelle (Paris)*, (4)7, Sect. C, no. 3, 189-213.
- Nebert, K., 1985. Kohlengeologische Erkundung des Neogens entlang des Ostrandes der Zentralalpen. *Archiv für Lagerstättenforschung der Geologischen Bundesanstalt*, 6, 23-77.
- Packard, J. M., 1984. Impact of manatees *Trichechus manatus* on seagrass communities in eastern Florida. *Acta Zoologica Fennica*, 172, 21-22.
- Papp, A., Rögl, F., Cicha, I., Ctyroka, J. and Pishvanova, S., 1978. Planktonische Foraminiferen im Badenien. In: Papp, A., Cicha, I., Senes, J. & Steininger, F. (eds.), M4 - Badenien (Moravien, Wielicien, Kosovien). *Chronostratigraphie und Neostratotypen*. 6, 268-278.
- Pervesler, P., Uchman, A. and Hohenegger, J., 2008. New methods for ichnofabric analysis and correlation with orbital cycles exemplified by the Baden-Soos section (Middle Miocene, Vienna Basin). *Geologica Carpathica*, 59, 395-409.
- Pervesler, P., Roetzel, R. and Mandic, O., 1998. Sirenenlagerstätten in den marinen Flachwasser-Ablagerungen der Eggenburger Bucht (Burgschleinitz-Formation, Eggenburgium, Untermiozän). *Geologisch-Paläontologische Mitteilungen Innsbruck*, 23, 87-103.
- Pervesler, P., Roetzel, R. and Steininger, F.F., 1996. Taphonomy of the Sirenians in the shallow marine sediments (Burgschleinitz-Formation, Eggenburgium, Lower Miocene) of Kühnring (Lower Austria). *Comunicación de la II Réunion de Tafo-nomía y fosilización*, pp. 319-326.
- Pervesler, P., Roetzel, R. and Steininger, F.F., 1995. Taphonomie der Sirenen in den marinen Flachwasserablagerungen (Burgschleinitz-Formation, Eggenburgium, Untermiozän) der Gemeindesandgrube Kühnring (Niederösterreich). *Jahrbuch der Geologischen Bundesanstalt*, 138(1), 89-121.
- Peters, K.F., 1867. Das *Halitherium*-Skelett von Hainburg. *Jahrbuch der Geologischen Reichsanstalt*, 17, 309.
- Pia, J. and Sickenberg, O., 1934. Katalog der in den österreichischen Sammlungen befindlichen Säugetierreste des Jungtertiärs Oesterreichs und der Randgebiete. *Denkschriften des Naturhistorischen Museums Wien (geologisch-paläontologische Reihe)*, 4, xvi + 544.

- Piller, W.E., Decker, K., and Haas, M., 1996. Exkursion A1: Sedimentologie und Beckendynamik des Wiener Beckens. [in:] Exkursionsführer 11. Sedimentologentreffen. Berichte der Geologischen Bundesanstalt, 33.
- Piller, W.E. and Vavra, N., 1991. Das Tertiär im Wiener und Eisenstädter Becken. In: Roetzel, R. & Nagel, D. (eds.), Exkursionen im Tertiär Österreichs, Molassezone Waschbergzone-Korneuburger Becken-Wiener Becken-Eisenstädter Becken. 161-216, Wien (Österreichische Paläontologische Gesellschaft).
- Piller, W.E., Egger, H., Erhart, C.W., Gross, M. Harzhauser, M. Hubmann, B., van Husen, D., Krenmayr, H.-G., Krystyn, L., Lukeneder, A., Mandl, G.W., Rögl, F., Rupp, C., Schnabel, W., Schönlaub, H.P., Summesberger, H., Wagreich, M. and Wessely, G., 2004. Die stratigraphische Tabelle von Österreich. Kommission für die paläontologische und stratigraphische Erforschung Österreichs der Österreichischen Akademie der Wissenschaften und Österreichische stratigraphische Kommission.
- Pilleri, G., 1987. The Sirenia of the Swiss Molasse with a descriptive catalogue of the fossil Sirenia preserved in Swiss collections. 114 pp. Brain Anatomy Institute, Ostermundigen (Switzerland).
- Pilleri, G., Biosca, J. and Via, L., 1989. The Tertiary Sirenia of Catalonia. 98 pp. Brain Anatomy Institute, Ostermundigen (Switzerland).
- Rabeder, J.K., 2001. Zur Sedimentologie und Geologie der Randfazies des Wiener Beckens: Das Lindabrunner Konglomerat. Masterthesis University of Vienna, 1-119.
- Rasser, M.W. and Harzhauser, M., 2008. Paleogene and Neogene of Central Europe. In: McCann, T. (ed.), The Geology of Central Europe. Volume 2: Mesozoic and Cenozoic. Geological Society, London, 1031-1140.
- Ratschbacher, L., Frisch, W., Linzer, H.G., 1991. Lateral extrusion in the eastern Alps, part II: structural analysis. *Tectonics*, 10(2), 257-271.
- Rögl, F., 1998. Palaeogeographic considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Annalen des Naturhistorischen Museums Wien*, 99A, 279-310.
- Rögl, F., 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). *Geologica Carpathica*, 50, 339-349.
- Rögl, F. and Steininger, F. F., 1983. Vom Zerfall der Tethys zu Mediterran und Paratethys. Die neogene Paläogeographie und Palinspastik des zirkum-mediterranen Raumes. *Annalen des Naturhistorischen Museums Wien*, 85A, 135-163.
- Rögl, F., Coric, S., Harzhauser, M., Jimenez-Moreno, G., Kroh, A., Schultz, O., Wessely, G., and Zorn, I., 2008. The Middle Miocene Badenian stratotype at Baden-Sooss (Lower Austria). *Geologica Carpathica*, 59, 367-374.
- Sabol, M. and Kováč, M., 2006. Badenian palaeoenvironment, faunal succession and biostratigraphy: a case study from northern Vienna Basin, Devínska Nová Ves-Bonanza site (western Carpathians, Slovakia). *Beiträge zur Paläontologie*, 30, 415-425.
- Sauer, R., Seifert, P. and Wessely, G., 1992. Guidebook to excursions in the Vienna Basin and the adjacent Alpine-Carpathian thrustbelt in Austria. *Mitteilungen österreichischen Geologischen Gesellschaft*, 85, 1-264.
- Schréter, Z., 1917. Mediterranes *Metaxytherium*-Skelett von Márcfalva. *Földtany Közlöny*, 47(1-3), 176-177.
- Seifert, P., 1996. Sedimentary-tectonic development and Austrian hydrocarbon potential of the Vienna Basin. In: Wessely, G. and Liebl, W. (eds.), Oil and gas in Alpidic thrustbelts and basins of central and eastern Europe. EAGE Special Publications, 5, 331-341.
- Sickenberg, O., 1927. Ein neuer Fund einer Sirene aus dem marinen Miozän des Burgenlandes. *Verhandlungen der Zoologisch-Botanischen Gesellschaft*, 77(3), 103-106.
- Sickenberg, O., 1928. Eine Sirene aus dem Leithakalk des Burgenlandes. *Denkschriften der Akademie der Wissenschaften Wien, mathematisch-naturwissenschaftliche Klasse*, 101, 293-323.
- Sorbi, S., 2008a. The Neogene Euro-North African Sirenia: phylogenetic and systematic study, palaeoecological and palaeobiogeographic considerations. Doctoral dissertation, Università di Pisa, Italy. 363 pp.
- Sorbi, S., 2008b. New record of *Metaxytherium* (Mammalia, Sirenia) from the lower Miocene of Manosque (Provence, France). *Geodiversitas*, 30(2), 433-444.
- Sorbi, S., Domning, D. P., Vaiani, S. C. and Bianucci G., 2012. *Metaxytherium subapenninum* (Bruno, 1839) (Mammalia, Dugongidae), the latest sirenian of the Mediterranean Basin. *Journal of Vertebrate Paleontology*, 32(3), 686-707.
- Spezzaferri, S., Ćorić, S., Stingl, K., Rögl, F. and Hohenegger, J., 2002. Bio- and magneto-stratigraphy and sequence biostratigraphy of the Karpatian-Badenian transition in the Styrian Basin. Evidence from the Wagna section. *PANGEO Austria*, 28-30.6.2002, Abstracts, p. 169.
- Stache, G., 1867. Die geologischen Verhältnisse der Fundstätte des Halitherium-Skelettes bei Hainburg an der Donau. *Verhandlungen der Geologischen Reichsanstalt Wien*, 1867(7), 141-144.
- Strauss, P., Harzhauser, M., Hinsch, R. and Wagreich, M., 2006. Sequence stratigraphy in a classic pull-apart basin (Neogene, Vienna Basin). A 3D seismic based integrated approach. *Geologica Carpathica*, 57, 185-197.

The sirenian *Metaxytherium* (Mammalia: Dugongidae) in the Badenian (Middle Miocene) of Central Europe

Šuklje, F., 1938. Mediteranska sirena iz Vrapča kod Zagreba i Otruševca kod Samobora. Glasnik Hrvatskoga Prirodoslovnoga Društva, 49/50, 87-93.

Švagrovský, J., 1978. 8. Faziesstratotypus: Devinska Nová Ves - Sandberg bei Bratislava. [In:] Papp, A., Cicha, I. Seneš, J. and Steininger, F. (eds.): Chronostratigraphie und Neostratotypen, M4, Badenien.

Thenius, E., 1952. Die Säugetierfauna aus dem Torton von Neudorf an der March (ČSR). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 96(1), 27-136.

Toledo, P.M., de and Domning, D.P., 1991. Fossil *Sirenia* (Mammalia: Dugongidae) from the Pirabas Formation (Early Miocene), northern Brazil. Boletim do Museu Paraense Emílio Goeldi, Série Ciências da Terra, 1, 119-146.

Tollmann, A., 1955. Das Neogen am Nordwestrand der Eisenstädter Bucht. Wissenschaftliche Arbeiten Burgenland, 10, 1-75.

VanderHoof, V.L., 1941. Miocene sea-cow from Santa Cruz, California, and its bearing on intercontinental correlation. Geol. Soc. Amer. Bull., 52(12), 1984-1985.

Wagreich, M., Pervesler, P., Khatun, M., Wimmer-Frey, I. and Scholger, R., 2008. Probing the underground at the Badenian type locality: geology and sedimentology of the Baden-Soos section (Middle Miocene, Vienna Basin, Austria). Geologica Carpathica, 59, 375-394.

Weissenböck, M., 1996. Lower to Middle Miocene sedimentation model of the central Vienna Basin. In: Wessely, G. & Liebl, W. (eds.), Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe. European Association of Geoscientists and Engineers Special Publication, 5, 355-364.

Wessely, G., 1961. Geologie der Hainburger Berge. Jahrbuch der Geologischen Bundesanstalt 104, 273-349.

Wessely, G., 1988. Structure and development of the Vienna Basin in Austria. American Association of Petroleum Geologists, Memoirs 45, 333-346.

Wiedl, T., Harzhauser, M. and Piller, E., 2012. Facies and syndimentary tectonics on a Badenian carbonate platform in the southern Vienna Basin (Austria, Central Paratethys). Facies, Online First™, 18 Januar 2012. DOI 10.1007/s10347-011-0290-0

Winkler, A., 1927. Die geologische Aufschlüsse beim Bau der Bahnlinie Friedberg-Pinkafeld und der geologische Bau des nordoststeirischen Tertiärbeckens. Verhandlungen der Geologischen Bundesanstalt, 1927(4), 97-103.

Wolsan, M., 1991. Pochodzenie i ewolucja ssaków morskich Polski. The origin and evolution of Polish marine mammals. Przegląd Zoologiczny, 35(3-4), 261-268.

Zbyszewski, G., 1944. Note sur la découverte d'un humerus de *Metaxytherium petersi* Abel dans l'Helvétien Vb de Lisbonne. Bol. Soc. Geol. Portugal, 4(1/2), 69-72.

Zuschin, M., Harzhauser, M. and Mandic, O., 2007. The stratigraphic and sedimentologic framework of fine-scale faunal replacements in the Middle Miocene of the Vienna basin (Austria). Palaios, 22, 285-295.

Received: 10 July 2012

Accepted: 6 September 2012

Daryl P. DOMNING<sup>1)</sup> & Peter PERVESLER<sup>2)</sup>

<sup>1)</sup> Laboratory of Evolutionary Biology, Department of Anatomy, Howard University, Washington, D.C. 20059, USA;

<sup>2)</sup> University of Vienna, Department of Palaeontology, Althanstrasse 14, A-1090 Wien, Austria;

<sup>\*)</sup> Corresponding author, peter.pervesler@univie.ac.at



# ZOBODAT - [www.zobodat.at](http://www.zobodat.at)

Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: [Austrian Journal of Earth Sciences](#)

Jahr/Year: 2012

Band/Volume: [105\\_3](#)

Autor(en)/Author(s): Domning Daryl P., Pervesler Peter

Artikel/Article: [The sirenian Metaxytherium \(Mammalia: Dugongidae\) in the Badenian \(Middle Miocene\) of Central Europe 125-160](#)